ATOMLAB 400
DOSE CALIBRATOR

OPERATION AND SERVICE MANUAL

086-335

BIODEX
Biodex Medical Systems, Inc.
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FN: 07-263 Rev C 10/13

ATOMLAB 400 DOSE CALIBRATOR

This manual covers installation and operation of the following product:

#086-335 Atomlab 400 Dose Calibrator

⚠ ***CAUTION:*** *Federal Law restricts this device to sale by or on the order of a physician, pharmacist or other licensed professional.*

⚠ ***ATTENTION:*** *La loi fédérale limite ce dispositif à la vente par ou sur l'ordre d'un médecin, du pharmacien ou de tout autre professionnel autorisé.*

ATOMLAB DOSE CALIBRATOR WARRANTY

1. Instrumentation

A. This equipment and its accessories are warranted by BIODEX MEDICAL SYSTEMS, INC., against defects in materials and workmanship for a period of two years from the date of shipment from BIODEX MEDICAL SYSTEMS, INC. During the warranty period, BIODEX MEDICAL SYSTEMS, INC. will in its sole discretion, repair, recalibrate or replace the equipment found to have such defect, at no charge to the customer.

EXCEPT AS STATED ABOVE, THERE ARE NO WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING WITHOUT LIMITATION WARRANTIES OR MERCHANTABILITY OR FITNESS FOR USE. BIODEX DOES NOT ASSUME LIABILITY FOR INCIDENTAL, CONSEQUENTIAL OR INDIRECT DAMAGES INCLUDING LOSS OF USE, SALES, PROFITS OR BUSINESS INTERRUPTION.

B. This warranty *does not* apply if the product, as determined by BIODEX MEDICAL SYSTEMS, INC., is defective due to abuse, misuse, modification or service performed by other than a BIODEX MEDICAL SYSTEMS, INC. authorized repair and calibration facility. Misuse and abuse include, but are not limited to, subjecting limits and allowing the equipment to become contaminated by radioactive materials.

C. In order to obtain warranty repair service, the equipment must be returned freight pre-paid to one of our facilities. The Return Materials Authorization number (R.M.A. #) should be included, along with a statement of the problem. Equipment will be returned transportation prepaid.

2. Calibration

A. Instruments are warranted to be within their specified accuracy at the time of shipment. If a question arises and BIODEX MEDICAL SYSTEMS, INC. determines that the initial calibration is in error, the instrument will be recalibrated at no charge.

B. Mechanical products are warranted to meet written specifications and tolerances at the time of shipment.

C. The return policy is as stated in paragraph 1.C.

3. Warranty is non transferable.

4. Non-Warranty Service

A. Repairs and/or replacements not covered by this warranty may be performed by BIODEX MEDICAL SYSTEMS, INC. at a factory authorized service location. Estimates of repair charges may be requested, however, a charge for estimate preparation may apply if the repair is later not authorized by the customer.

B. The cost of transportation into and out of the service location will be the responsibility of the customer.

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Service Procedure

If you think you have a service problem, take the following action.

1. Check to see that the problem occurs more than once.

2. Check the instruction manual and operations procedure.

3. Check the instruction manual Trouble-shooting Guide.

If you still think you have a service problem, call BIODEX MEDICAL SYSTEMS, INC., Service Department at (800) 224-6339.

Keep yourself and the phone next to the equipment.

1. Service will ask you for a brief description of the problem. We will ask specific questions about the malfunction that occurred. This diagnostic process may take a few minutes, so call us when you have time to spare.

2. After taking the information, we will advise on the action we will take.

3. Sometimes service personnel must consult with engineering and it may take time to get back to you. Be sure to let the service representative know your schedule so that we can call at a convenient time.

4. The return call may be from a person other than whom you first reported the problem to.

5. After analyzing the problem, we will decide if the unit must be returned to us for repair, or replacement parts will be sent.

6. If unit must be returned, it will be given a Return Materials Authorization number (R.M.A. #) by us. Pack the system in the carton that it was originally shipped in, or pack it safely and securely to avoid shipping damage. It is the customer's responsibility for any damage that occurs during shipping.

7. Non-warranty/non-service contract charges for repair are as follows:
   a. Materials
      +
   b. Time
      +
   c. Shipping Charges

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PACKING SLIP

Shipping Cartons:
The Atomlab 400 Dose Calibrator and its respective components comes carefully packed in two cartons inside a large, single shipping box. One carton contains the Display Unit in a carton and the Vial/Syringe Dipper in a foam holder and the power pack and Warranty cards in a small box. The other carton contains the Detector unit.

NOTE: *Prior to removing any of the cartons from the shipping box, visually inspect the box and the inside packing for damage. If any damage is noted, do not unpack the contents. Notify the carrier immediately so that a claim can be made if necessary, and contact your Biodex Medical Systems Sales Representative. If there is no visible damage, remove the cartons and place them on a table or to the side. We suggest removing the DISPLAY UNIT carton first.*

NOTE: *Before deciding on a location to set up your Atomlab for operation, be sure to read Chapter Two on installation. This chapter notes operating and environmental requirements, and offers several tips on choosing a location for your dose calibrator.*

The DISPLAY UNIT Carton:
The Display Unit Carton also contains the Atomlab Operation Manual, Report of Calibration, the Vial/Syringe Dipper in a foam holder and a small box containing the power cord, power pack and chamber to display cable.

The DETECTOR UNIT Carton:
This carton contains the detector and well liner (inserted into the chamber).

⚠ ***CAUTION:*** *The carton labeled DETECTOR UNIT is very heavy, ~38 pounds. Severe damage to the unit may result if this carton is dropped. Remove the detector from the carton and carefully place it on the table or other counter where you will set up and use your Atomlab unit. Make certain the table top will support a minimum of 300 pounds. We suggest that you place the carton on its side so that you can slide the Detector Unit out of the carton onto its base. Inserted into the Chamber Well should be a Chamber Well Liner.*

⚠ ***ATTENTION:*** *Le carton étiqueté UNITÉ DE DÉTECTION est très lourd, ~38 livres. Cet appareil peut subir de sérieux dommages s'ii est échappé. Retirez le détecteur de son carton et utiliserez le avec prudence sur la table ou le computoir où vous installerez et utiliserez l'unité Atomlab. Assurezvous que la table supportera un minimum de 300 livres. Nous suggérons que vous placiez le carton sur son côté afin que vous puissiez faire glisser L'UNITÉ DE DÉTECTION du carton à sa base. Dans la chambre du calibrateur vous devriez trouver un manchon protecteur. Un échantillon en plastique est emballé avec l'unité de présentation.*

NOTE: *Do not discard the packing materials, cartons or shipping boxes. You will need them should it become necessary to return any of the Atomlab components in the future.*

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CHAPTER 1: ATOMLAB 400 INTRODUCTION

Atomlab Dose Calibrators use an argon gas filled pressurized chamber to measure the activity of a radionuclide source of a known isotope. Their primary application is the measurement of the dose administered to a patient in nuclear imaging or nuclear medicine.

The Atomlab dose calibrator is comprised of a display unit and a connected ionization chamber detector unit. It provides fast, accurate radionuclide activity measurements with performance that easily surpasses the most stringent regulatory requirements.

With its small footprint, the Atomlab 400 fits easily into even tight work areas. The display screen features large, easy to read prompts and activity readings. Selections are made via screen labeled buttons and data can be exported to a computer program via an RS-232 cable.

Figure 1.1. Compact and lightweight, the Atomlab 400 also features large, easy to read display values.

This system features 10 factory pre-set routine isotope buttons, an alphabetical isotope list, seven set buttons that can be designated from the full alphabetical isotope list of 87 isotopes (including Y-90 and Sr-89,) plus two new (custom) user-defined isotope set buttons.

Activity is displayed in either Curie or Becquerel units. Background zero adjustment is performed at the touch of a key while activity range selection is automatic. Activity measurements are performed by a microprocessor-controlled electrometer located at the base of the detector assembly of the ionization chamber. The chamber is shielded with .25" (.64 cm) of lead. It can be located up to eight feet away from the display unit. The display unit can be wall mounted or set on the table top. Chamber bias is generated within the chamber unit by an electronic high voltage supply, eliminating the need for expensive battery charges.

The Atomlab 400 is covered by an industry exclusive two-year warranty.

INTENDED USE

The Atomlab Dose Calibrator is intended to measure the activity of a radioactive source of a known isotope. This measurement may be for purposes of determining or verifying a radiopharmaceutical dose for nuclear imaging or nuclear medicine. This measurement may also be for the purpose of determining the radioactivity of a sample for dose calibrator constancy and accuracy testing or to measure other non-medical radioactive samples.

INDICATIONS FOR USE

The Atomlab Dose Calibrators are used in Nuclear Medicine Departments, clinics and nuclear pharmacies to measure radioactive doses for administration to patients.

The instrument is used to verify the radioactivity of a radionuclide before administration to the patient.

IMPORTANT NOTES FOR ATOMLAB DOSE CALIBRATOR USERS

The Atomlab Dose Calibrator you have purchased is a high-quality, dependable and reliable instrument. Before using it, please review the following points.

Before using this device, be certain to read the entire operation manual. Failure to read the manual may result in user error or inaccurate data.

The Atomlab Dose Calibrator should be used only as specified in the operation manual.

The Atomlab Dose Calibrator is designed for use in a patient environment.

Quality Assurance Testing of Atomlab Dose Calibrators is provided in Appendix J.

CHAPTER 2: ATOMLAB 400 INSTALLATION

We strongly suggest that you read this chapter before moving on to the operation chapter. This will help ensure that your Atomlab Dose Calibrator is up and running properly, and that you have adequate access to the unit to perform all the functions that will be discussed.

OPERATING REQUIREMENTS

Prior to installing your equipment, plan a layout for your Atomlab unit that will ensure it is convenient for measuring radionuclides and will not cause undue radiation exposure because of extra handling of high activity sources. There should be ample room to place a vial shield on the work surface (preferably behind an L-Block shield), open the shield and remove the vial using tongs, quickly place the vial into the vial/syringe dipper and then place both into the Chamber Well.

Remember that to make radioisotope measurements you will have to place the clear plastic Chamber Well Liner into the Chamber Well and lower the plastic vial/syringe dipper into the liner. Make sure there will be no obstructions, such as wall cabinets, above the Detector Unit. Such obstacles may make it difficult to insert and remove the vial/syringe dipper.

NOTE: *You must use a well liner at all times.*

Work Surface

Choose a table or other counter which is free of vibration, does not wobble, and will easily support 300 pounds.

The surface area of the table top should provide ample area to accommodate the Detector Unit, Display Unit, the L-Block Shield, the shielded radionuclide preparation area, and room for writing.

Suggested dimensions of the table top are:

- 30 in. deep
- 48 in. wide
- 36 in. high

Physical Location and Environment

Frequently, dose calibrators are located in areas called hot labs in which there is a wet sink with plumbing. Do not locate your dose calibrator on a table or other counter which can become wet or is subject to splashing or spraying.

Avoid areas which have drafts caused by heating or air conditioners, or are in direct sunlight. Electronics work best when constant temperature is maintained.

The temperature range is from 0 to 40° C, and the relative humidity range from 0 to 90%.

Choose a location for your dose calibrator which is not frequently used by other personnel — one where the table on which it lies will not be bumped.

In general, make sure your work area is clean, dry, and dust free.

Avoid locating your dose calibrator near a radioactive materials storage area. The .25-inch lead shield around the detector shields it from changes in radiation levels from diagnostic energy radionuclides (i.e., Tc-99m); however, the high energy radiation from sources such as Cs-137, F-18 and Co-60 will easily penetrate the shield and change the background radiation level. The lower the ambient radioactivity, the less background activity for which the Atomlab Dose Calibrator must compensate, and, the greater the accuracy and reliability of the readings.

Power Requirements

Choose a line power source with a socket which mates securely with the power plug provided.

Verify that the power line is properly grounded.

Do not choose an outlet that has a wall switch control.

This system uses APS (Advanced Power Solution) Power Supply for Medical use, model #APS22ES-150160.

Line Voltage:
100 to 240 VAC, auto selectable by the power supply.

Line Frequency:
50/60 Hz.

Positioning

After you have chosen a suitable location for your Atomlab Dose Calibrator and familiarized yourself with its components, position the various units. Make sure the Detector and Display Units have been positioned to where they will not have to be moved prior to connecting the cables.

CABLE CONNECTIONS

(See Figures 2.1 and 2.2.)

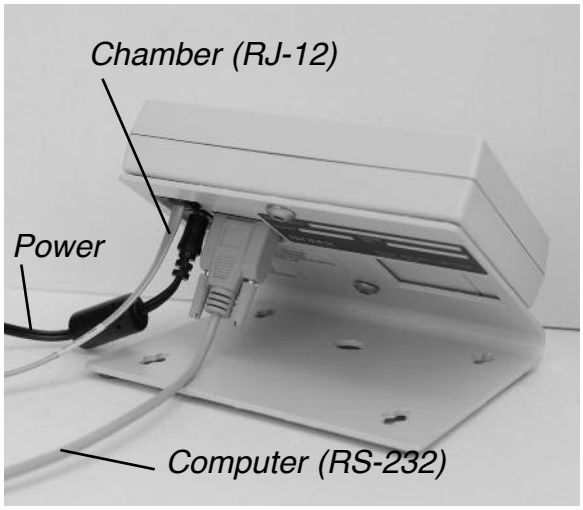

Figure 2.1 Atomlab 400 cable connections.

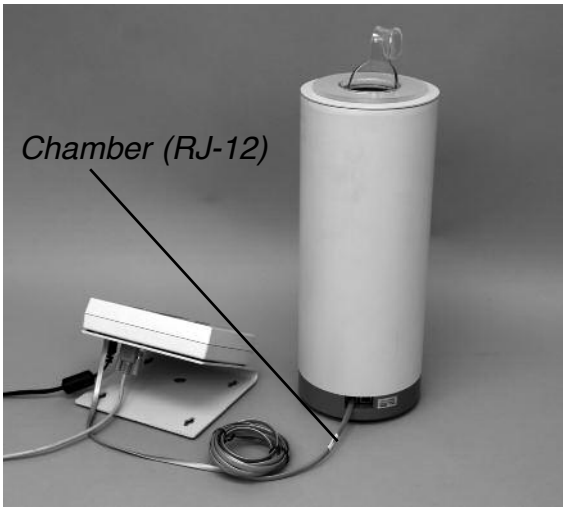

Figure 2.2 Atomlab 400 display connected to a chamber.

1. Rotate the detector unit to access the connector on the base of the detector.
2. Insert one end of the RJ12 detector cable into the mating detector port.
3. Rotate the detector unit to its normal position so that the detector jack is facing away from the work area.
4. Rotate the display unit to access the connection ports located on the underside of the display.
5. Insert the free end of the detector cable into the mating display port.
6. If you would like to connect a computer to the Atomlab 400, attach an RS-232 cable with a DB9 connector to the serial port and then attach the opposite end of the cable to the appropriate port on the computer.
7. Insert the free end of the power supply cord into the power port on the display unit.
8. Insert the small end of the power cord into the black, rectangular power supply box. The display should turn ON once the power cord is plugged into the wall and the system test will run automatically to check for proper function of the CPU, RAM, Firmware, Program and Chamber. It will then automatically perform a background measurement as part of the power-up process.

NOTE: *As long as the Atomlab 400 is plugged in and power turned ON, the system will be functioning. Depending on the Backlight Time setting, the display screen will eventually turn OFF. Press any key on the display to reactivate the display screen. You can still set the display with the backlight off.*

POWER UP
(See Figure 2.3.)

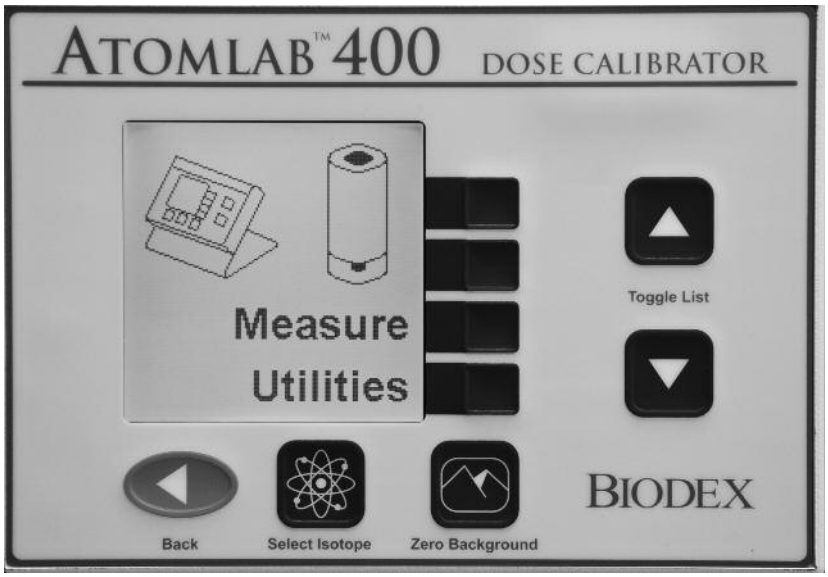

Figure 2.3. The Atomlab 400 Home Menu.

Once the system check is completed, press the <Screen Key> next to the "Continue" prompt to advance to the opening menu, or take appropriate action to correct any errors noted on the display such as connecting the chamber if the "Chamber Not Found" prompt appears.

The Atomlab 400 Home Menu allows the user to proceed with measuring or advance to the Utilities Menu.

NOTE: *After turning your Atomlab ON and completing the Self-Test for the very first time, do not press any keys for at least an hour. This allows the sensitive electronics to stabilize. The backlight will turn OFF when no button has been pressed on the calibrator for an hour. You can still see the display with the backlight off. When you press a button, the backlight comes on. If you turn the Dose Calibrator OFF, when you turn it back on, you should wait several minutes for the electronics to stabilize before using it. If it is turned OFF for a prolonged period of time or moved to another location, you should wait longer for it to stabilize before use.*

PACKING MATERIAL

Now that you have set up your Atomlab Dose Calibrator, and everything is intact and functioning properly, take a few moments to repack the packing material. This material was especially designed for safe shipment of the Atomlab Dose Calibrator and should be considered part of the instrument. Place the shipping material in the appropriate boxes and put the boxes back into the shipping carton. Label the carton and store it in a safe, out-of-the-way location. If you ever need to return your dose calibrator for updates, calibration, or repair, use the original shipping carton, boxes, and shipping material.

MAINTENANCE

General Cleaning Instructions

As required, wipe down the exterior of the unit using a soft rag slightly dampend with alcohol or a mild soap solution.

Quality Assurance Testing

To properly maintain your Atomlab Dose Calibrator, quality assurance should be performed as suggested in Appendix J: Quality Assurance Testing of Atomlab Dose Calibrators.

CHAPTER 3: OPERATION

KEY FUNCTIONS

(See Figure 3.1.)

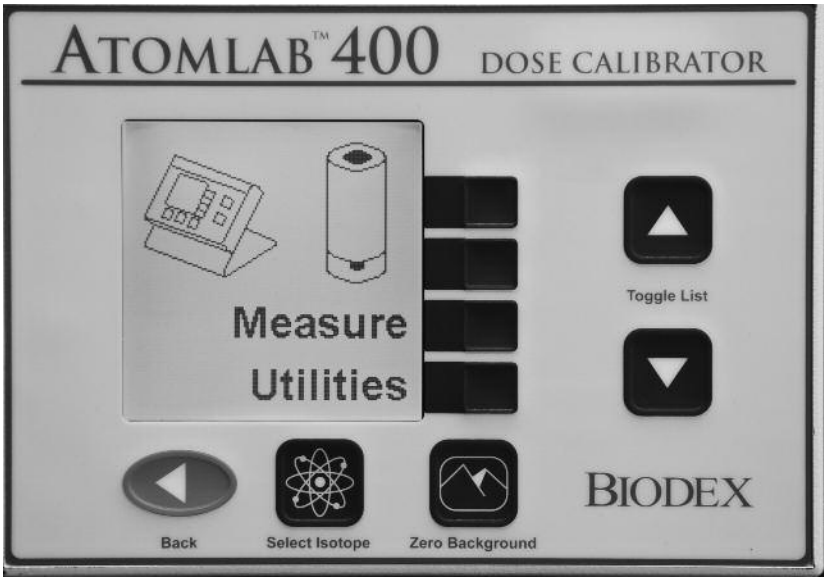

Figure 3.1. Atomlab 400 key functions.

Compact and easy to use, the Atomlab 400 makes use of simple keys that interact with the internal firmware program. Key functions are as follows:

- <Back>: Return to the previous screen.
- <Select Isotope>: Allows selection of a specific isotope from the isotope list.
- <Zero Background>: Used to zero the background reading before performing a measurement.
- <Screen Keys>: These are the four keys located immediately to the right of the display screen. Press any key to select the adjacent prompt. Only keys adjacent to a prompt are active.
- <Toggle List>: Allows the user to scroll through any list displayed. Use the <▲>key to scroll up the list and the <▼> to scroll down the list.

MEASURING AN ISOTOPE

(See Figure 3.2.)

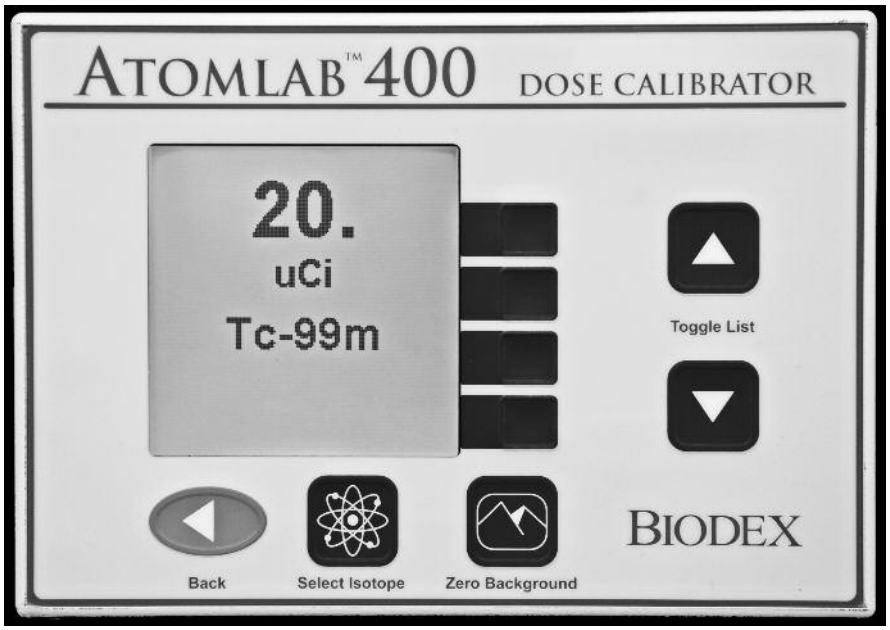

Figure 3.2. The Measure screen.

Selecting <Measure> from the Home Menu allows counting of the currently selected isotope. The screen defaults to the last selected isotope, or to Tc-99m if no prior isotopes have been selected. All readings are live and displayed while the chamber is reading. The system selects the most recently used units of measure (mCi or Becquerels,) or defaults to μCi if units have not been previously selected.

To Measure An Isotope:

1. Press <Select Isotope> if the isotope desired is not displayed.
2. Press the appropriate isotope key, or use the <Toggle List> keys to scroll up and down through the isotope list.
3. Place the isotope in the chamber. The activity level is immediately displayed.
4. Press <Back> to return to the Home Menu, <Select Isotope> to select a different isotope to measure, or <Zero Background> to zero the background measurement.

NOTE: *If you select Mo-99, the system will prompt you to wait at least 30 seconds for the activity reading. For all other isotopes, the activity reading should settle almost immediately.*

CHANGING ISOTOPES

(See Figures 3.3 and 3.4.)

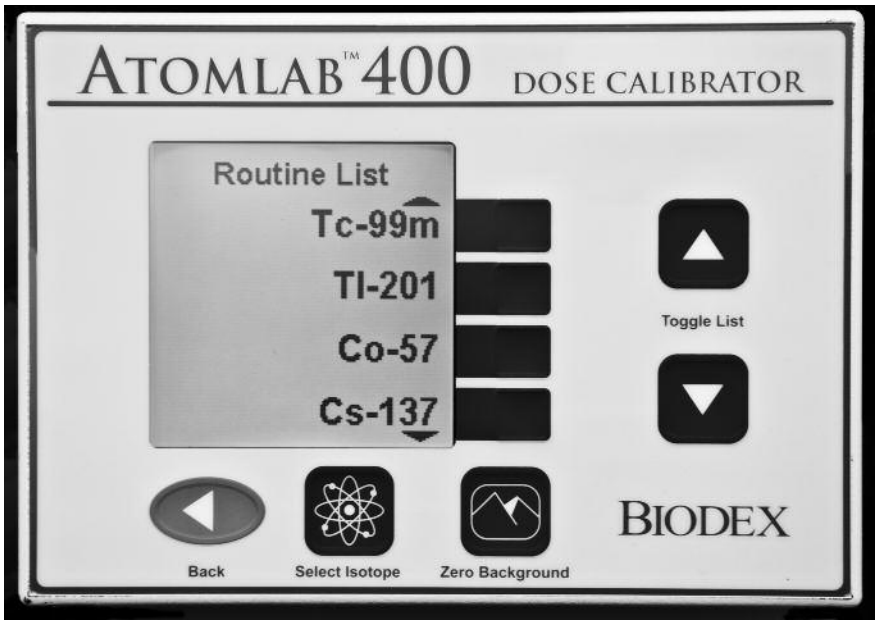

Figure 3.3. The Routine List.

The selected isotope can be changed at any time and the display will immediately read the new isotope selected. There are two lists from which isotopes can be selected.

The Routine List, displayed when you press <Select Isotope>, shows 10 commonly used preset isotopes, seven <Set Button> keys that isotopes can be assigned to, plus two user-defined custom isotopes.

The Full Alphabetical List is accessed by choosing “Select From List” below the Routine List. This list shows an alphabetical listing of all isotopes (having an analytically determined dial value) which the Atomlab 400 is designed to measure. (Figure 3.4)

To Change Isotopes:

1. Press <Select Isotope>. The Routine List is displayed.
2. Use the <Toggle List> keys to scroll up and down through the isotope list.
3. Press the <Screen Key> to the right of the desired isotope. The system returns to the Measure screen with the selected isotope displayed.

To Access the Alphabetical List and Select an Isotope:
1. Press <Select Isotope>. The Routine List is now displayed.
2. Use the <Toggle List> keys to scroll through the Routine List and press the <Screen Key> to the right of the “Select From List” prompt. The Full Alphabetical List is now displayed.
3. Use the <Toggle List> keys to scroll up and down through the Full Alphabetical List.
4. Press the <Screen Key> to the right of the desired isotope. The system returns to the Measure screen with the selected isotope displayed.
5. Using this option, the selected isotope is not maintained by the Routine List and will have to be selected again from the Full Alphabetical List if you change isotopes at any point.

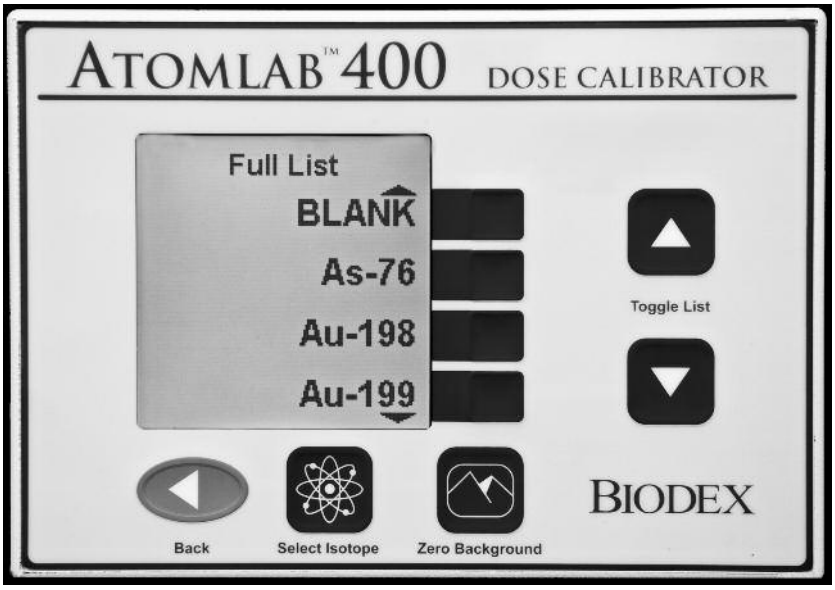

Figure 3.4. The Alphabetical List provides an alphabetical listing of all isotopes for which the Atomlab 400 is designed to measure.

SETTING AN ISOTOPE

(See Figure 3.5.)

To specifiy an isotope to match one of the Set <Screen keys>:
1. Press <Select Isotope>. The Routine List is displayed.
2. Use the <Toggle List> keys to scroll to any of the seven “Set Button” prompts. (See Figure 3.5A)
3. Press the <Screen Key> to the right of the “Set” prompt to access the Full List.(See Figure 3.4)

4. Use the <Toggle List> keys to scroll up and down through the Full List and press the <Screen Key> to the right of the desired isotope.
5. Press the <Screen Key> to the right of the “OK” prompt to set the selected isotope and add it to the Routine List. Press the <Screen Key> next to the “Cancel” prompt to return to the full list. (See figure 3.5B)
6. If you have selected to set the isotope, the system returns to the Measure screen with the selected isotope displayed. If you cancelled the set operation, the system returns to the Full List.

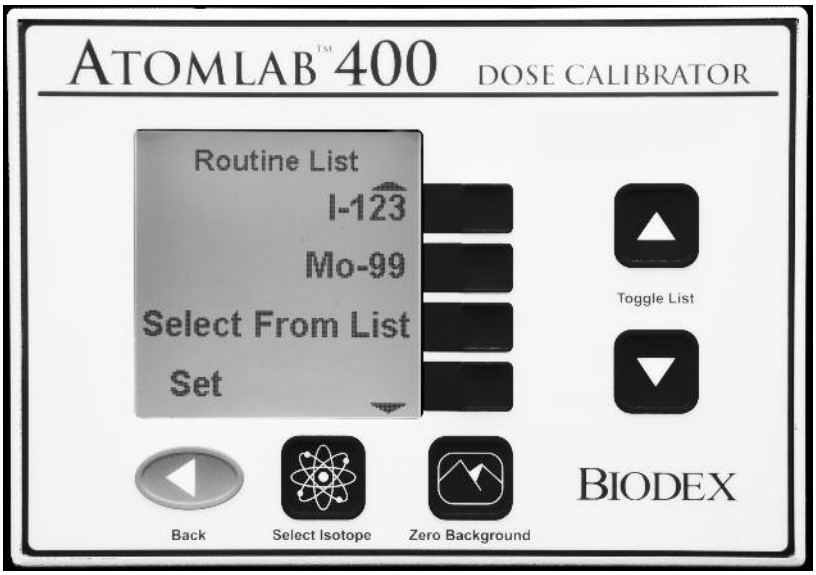

Figure 3.5A. Set Button Selection showing first set button prompt.

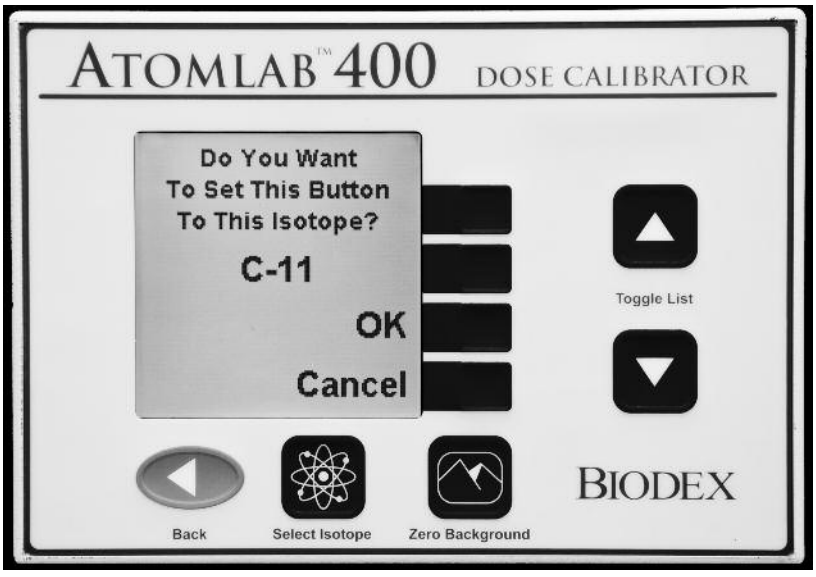

Figure 3.5B. The Set Button Confirmation screen.

DEFINING AN ISOTOPE

(See Figure 3.6.)

The Atomlab 400 allows two user-defined isotopes. To define an isotope:

1. Press <Select Isotope>. The Routine List is displayed.
2. Use the <Toggle List> keys to scroll to either of the “New Isotope” prompts.
3. Press the <Screen Key> to the right of “New Isotope” to access the Dial Value screen.
4. Use the <Toggle List> keys to dial in the value desired. Hold the toggle keys down to increase scroll speed.
5. Press the <Screen Key> next to “OK” to select the value entered and return to the Measure screen with the new isotope selected. Press the <Screen Key> next to “Cancel” to cancel the operation and return to the Routine List.

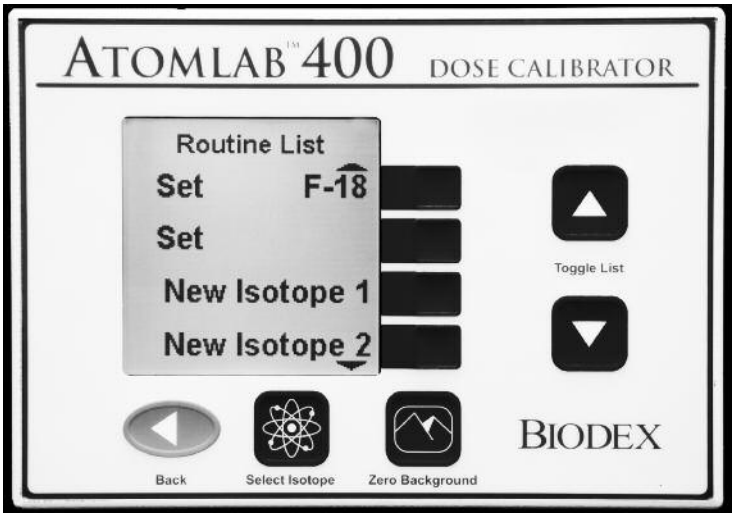

Figure 3.6. “New Isotope” settings on the Routine List allow the user to define two custom isotopes.

ZERO BACKGROUND

(See Figure 3.7.)

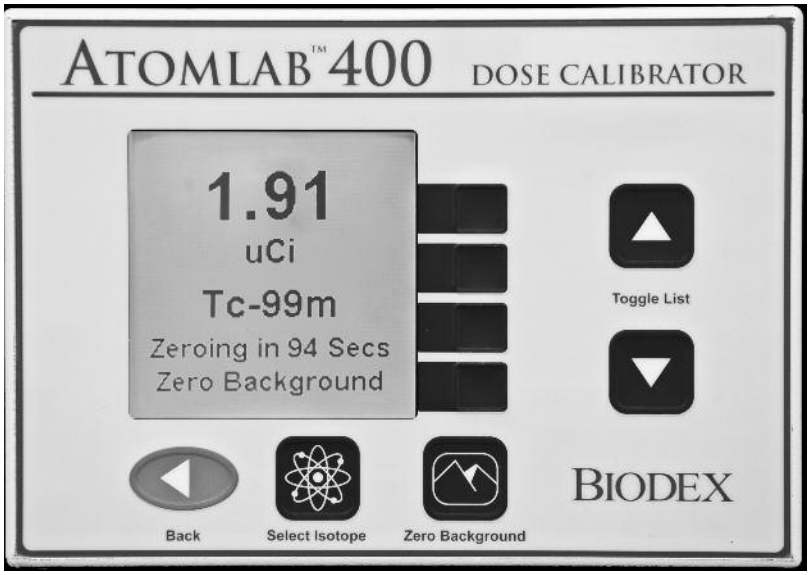

Figure 3.7.

The Zero Background feature is used to zero the background reading before measuring an isotope. The Zero Background screen is accessed by simply pressing the <Zero Background> key. The isotope displayed is always the last one selected, or Tc-99m if no isotope has been selected. Measurement units default to the last selected (Curies or Becquerels,) or to Curies if no measurement units have been selected.

If no isotopes have been put into or taken out of the chamber within the last 100 seconds (chamber poles,) pressing <Zero Background> displays the Zero Background screen for one second, the background is reported as 0, and the system returns immediately to the previous screen.

To Zero Background:

1. Press <Zero Background>. The Zero Background screen is displayed. The message “Zeroing in XXX seconds” is displayed with the time counting down to zero from the point the isotope was actually removed.
2. If desired, you can adjust the background reading resolution using the <Toggle List> keys.
3. At the end of the countdown, 0.0, the previous screen is displayed.
4. Pressing <Zero Background> starts the process again if, for example, the user accidentally leaves an item in or near the chamber and the unit has completed the background count.

NOTE: *Even though the Atomlab Dose Calibrators compensate for background interference, the accuracy of Activity Measurements depends on the intensity of the background radiation. For this reason, store the new generator, old generators and check sources away from the dose calibrator.*

NOTE: *If you start a background count with a source in or near the chamber, you can abort or stop the background count by removing the source, pressing <Back>, putting a source into the chamber to get an activity reading, then removing the source and pressing <Zero Background> to restart the zero background procedure at 100 sec.*

CS-137 CONSTANCY CHECK TEST

After the zero background correction has been completed, remove your Cs-137 calibration reference source from its shield, place it in the vial/syringe dipper and lower it into the Chamber Well.

Press the **Cs-137** key. The Activity Display will now show the activity of your Cs-137 reference source.

Compare the displayed activity with the decayed calculated activity (for an example of how to calculate a decayed activity see Appendix D: Decay Calculation.) For a properly calibrated source above 100 μCi, the displayed value should be within a few percent of the decayed calibrated value.

NOTE: *If you do not have a Cs-137 source, use a calibrated Co-57 source and press the* ***Co-57*** *key to perform the above steps.*

NOTE: *Both the Chamber Well Liner and vial/syringe dipper should be periodically checked for contamination as described later in this chapter (the more your dose calibrator is in use, the greater the frequency of contamination checks required).*

Many users use two reference sources to perform constancy checks.

These calibration reference sources provide a vital quality assurance test which should be done daily to assure proper performance of the calibrator.

ISOTOPE RESPONSE PERIOD

The Atomlab 400 normally settles within three seconds as long as the threshold level is exceeded. When you first lower the source into the well, the activity value quickly jumps to the final value. For a few seconds the value may fluctuate, but then the value settles down to a small variation. As soon as the source is removed from the Chamber Well, the Activity Display will drop down to the near zero value.

MOLY BREAKTHROUGH TEST

A Moly Breakthrough Test is an evaluation of the amount of Mo-99 contamination in a vial or syringe of Tc-99m. Tc-99m, a decay product of Mo-99, is obtained from a generator by leaching it from the column of Mo-99 after it is formed.

The test method has been derived from the fact when Mo-99 decays, high energy gamma photons (~750 keV) are produced which can "breakthrough" a lead wall with a thickness sufficient to totally absorb the lower energy Tc-99m gamma (~140 keV). Therefore, when a Tc-99m source is placed in a properly shielded lead container and inserted into the Chamber Well of the Atomlab 400, any measured radiation will be due to Mo-99 gamma transmission.

NOTE: *The* ***Mo-99*** *key has been calibrated to measure the activity of Mo-99 in a sample contained within the optional Moly Breakthru Shield.* ***You must use this breakthrough shield.*** *Failure to do so may result in inaccurate results. The Activity Display will show a direct readout of the activity, which means that corrections for wall absorption have been included in the Calibration Value.*

NOTE: *Although the Mo-99 countdown is intended to suggest an adequate time frame, the Atomlab 400 will continue to acquire Mo-99 data as long as the Mo-99 key is selected. As a general rule, the longer you wait, the more stable the reading.*

ISOTOPE SELECTION KEY CALIBRATION

If you have an isotope whose activity has already been accurately calibrated, such as a source obtained from the National Institute of Standards & Technology, you may use it to set a Calibration Value for any of the Standard Isotope Selection keys. The procedure is as follows.

1. Obtain the calibrated activity and its date.

For example, the National Institute of Standards & Technology source you obtained is I-125 with the following properties:

Activity measured: 12/13/88, 12:00 EST
Activity per unit mass: 1.195 MBq/g ±0.005 (±0.5%)
Mass: 4.95863 g

The half-life is 59.6 days ±0.2

Let A = current activity
A_0 = activity at time of calibration

$A = A_0 e^{-\ln(2)(t/T_{1/2})}$
where t = time lapse since calibration and T1/2 = half life

A_0 = (1.195 MBq/g)(4.95863 g)
= 5.926 MBq
= 160.2 μCi

t = 60.25 days
$A = 160.2\ e^{-\ln(2)(60.25/59.6)}$
= 79.5 μCi (2.94 MBq)

2. Calculate the current activity. Compare this value to the source reading in the chamber. If you want to change the dial setting note that this will also change the activity displayed. See the next step.
3. On the Home Menu, press <Utilities>.
4. Select <Dial Values> from the Utilities screen.
5. Select the isotope for which you would like to adjust the dial value by using the <Toggle List> keys to scroll up and down to the desired isotope, then press the desired isotope button.
6. Make a note of the original dial value.
7. Use the <Toggle List> keys to raise or lower the dial value.
8. Press <OK>.
9. Press <OK> again to confirm the dial value change.
10. Press <Back> twice to return to the opening screen.

11. Press <Measure> and take a reading. If the reading matches the calculated activity use that dial setting. If the reading does not match, repeat steps 3 through 10 until you get a matching activity reading.

    NOTE: *This will be the dial setting used until you change it. Make a note of the revised setting. An * will be placed next to the isotope for which you adjusted the dial setting.*

CHECKING THE STANDARD KEYS

From time to time you may wish to check the Calibration Dial Values of the Routine and Alphabetical Isotope Selection Keys. To check the dial values, at Home Screen press <Utilities> and then <Toggle List> to Dial Values. Press <Dial Values>. Any isotope that has been changed will appear with an ***** in front of it. If you press that isotope you will see the current dial setting. Compare this to the Pre-Set Calibration Values in Appendix E.

CONTAMINATION CHECKS

Vial/Syringe Dipper Check

To ensure that your vial/syringe dipper is not contaminated, perform the following steps:

1. Remove the vial/syringe dipper from the Detector.
2. Ensure that the Activity Display reads less than ±0.05 μCi. If not, use the <Zero Background> key to correct for the change in background radiation, thus zeroing the background
3. Place the vial/syringe dipper into the Chamber Well.
4. Press <Select Isotope> then <Toggle List> to dispay Mo-99.
5. Press the <Screen> key next to Mo-99 to begin 30 sec countdown. If, after the 30-second countdown on the Display, the activity is > 2μCi, set the vial/syringe dipper aside. Repeat test steps 1 – 5 the next day or after a weekend. If, after the repeat test, the activity is still > 2μCi, you need to order a replacement vial/syringe dipper because of contamination.
6. If the activity is < 2μCi, place the vial/syringe dipper back in the Chamber Well and, if the activity value now reads greater than 0.05 μCi, press <Zero Background> again.
7. You can now use the dipper.

Detector Liner Check

Repeat the above procedure, but only remove and replace the Well Liner. Do not use the dipper for this test.

CHAPTER 4: ATOMLAB 400 UTILITIES

THE UTILITIES MENU

(See Figure 4.1.)

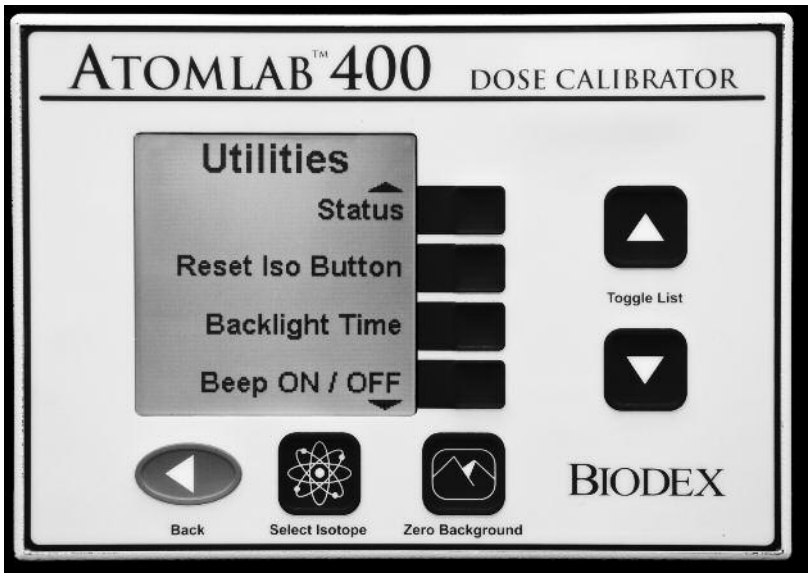

Figure 4.1 The Utilities Menu. Use the <Toggle List> keys to view additional Utility Menu options.

Selecting <Utilities> from the Home Menu allows access to the Utilities Menu. Use the <Toggle List> Keys to scroll up or down the Utilities menu and then press the appropriate <Screen Key> to choose desired function.

Selections on the Utilities Menu include:

Status
Reset ISO Button
Backlight Time
Beep ON/OFF
System Test
Change Units
Dial Values
Factory Defaults
Source Threshold

STATUS
(See Figure 4.2.)

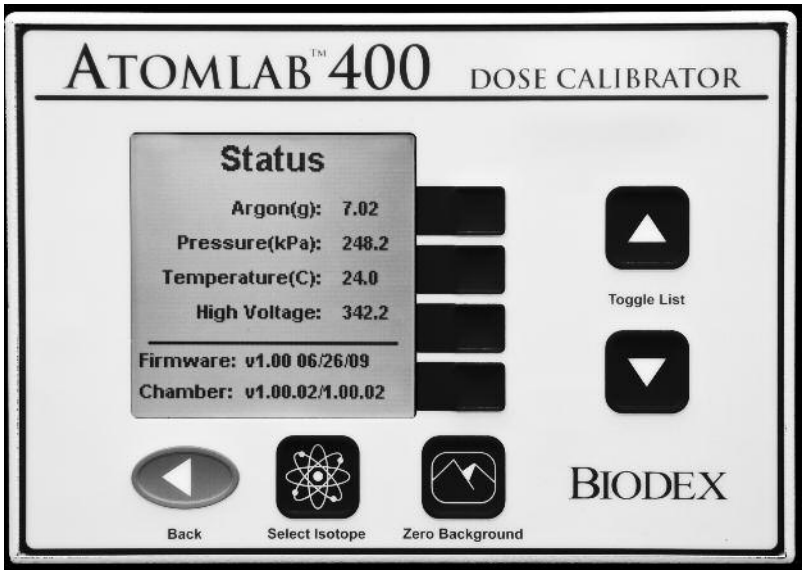

Figure 4.2. The Status screen.

The Status screen is used to check the status of various system parameters. It displays values for Argon(g), Pressure (kPa), Temperature (C) and High Voltage.

The Status screen also displays the current Firmware version and Chamber version.

RESET USER-DEFINED BUTTONS

(See Figure 4.3.)

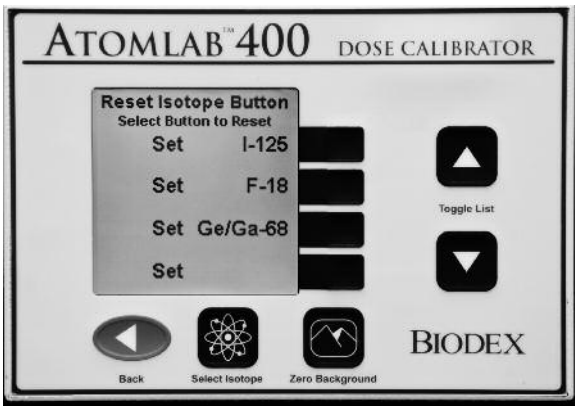

Figure 4.3. The Reset Isotope Button screen.

The Reset ISO Button is used to set the initial isotope value for user-defined isotopes or to reset the isotope value for any isotope that has been defined by the user.

A. Setting Initial "Set" Button Values For User-Defined Isotopes

1. Press the <Screen Key> opposite the “Reset Iso Button” prompt. The Reset Isotope Screen is displayed.
2. Use the <Toggle List> keys to scroll through the “Set” prompts list
3. Press the <Screen Key> opposite the <Set> prompt to access a full alphabetical listing of isotope values.
4. Use the <Toggle List> keys to scroll the list to display the desired isotope.
5. Press the <Screen Key> opposite the desired isotope from the Full Isotope List.
6. Press the <Screen Key> next to the "OK" prompt to set the <Set> button for the desired isotope and return to the Reset Isotope Button selection screen, or press the <Screen Key> next to “Cancel” to exit without changing the key value.
7. Press <Back> to return to the Utilities Menu.

B. Resetting Initial "Set" Button Values For User Previously Defined Isotopes

1. Press the <Screen Key> opposite the “Reset Isotope Button” prompt. The Reset Isotope Screen is displayed.
2. Press the <Screen Key> opposite the desired <SET> button your want to change.
3. Press the <Screen Key> next to the “OK” prompt to respond to the “Do You Want To Re-Set This” prompt.
4. The display now shows a full alphabetical listing of isotope values.
5. Use the <Toggle List> keys to scroll the list to display the desired isotope.
6. Press the <Screen Key> opposite the desired isotope from the Full Isotope List.

NOTE: *To Clear the Set Button select <Blank>.*

7. Press the <Screen Key> next to the “OK” prompt to set the selected set button for the desired isotope and return to the Reset Isotope Button selection screen, or press <Cancel> to exit without changing the set button value.
8. Press <Back> to return to the Utilities Menu.

BACKLIGHT TIME
(See Figure 4.4.)

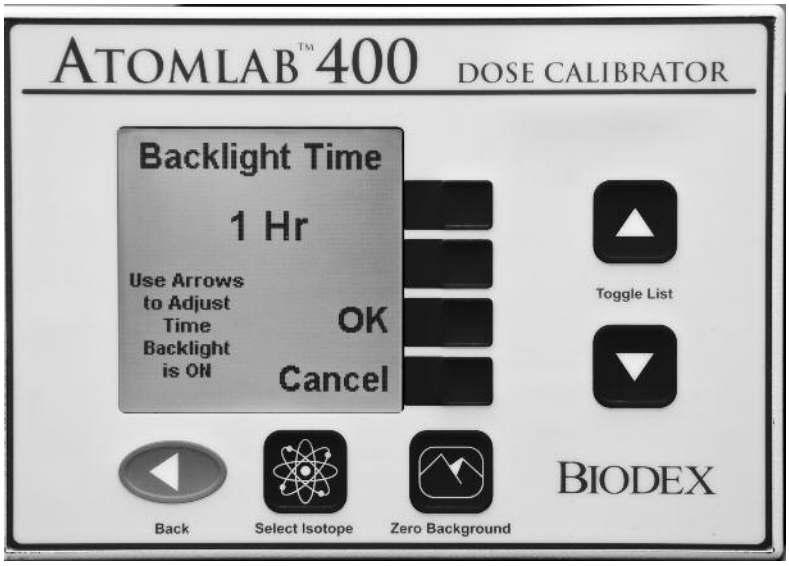

Figure 4.4. The Backlight Time screen.

The backlight feature illuminates display values and is adjustable in one-hour increments.

1. Press the <Screen Key> opposite the Backlight Time prompt to access the Backlight Time screen.
2. Use the <Toggle List> keys to increase or decrease the length of time the backlight is ON.
3. Press the <Screen Key> opposite the “OK” prompt to set the new backlight time value and return to the Utilities Menu, or press the <Screen Key> opposite “Cancel” to exit without changing backlight value.

NOTE: *The minimum time is one hour. Adjustments are made in one-hour increments up to approximately 10 hours*

NOTE: *If the backlight goes off, press any button to turn it back ON.*

BEEP ON/OFF
Use this setting to enable or disable the audio beep that confirms your selections.

1. Use the <Screen Key> opposite the desired choice to either enable or disable the audio beep. Once the desired key has been pressed, the system returns to the Utilities Menu. If you did not make a change and the ON or OFF is not changed, press <Back> to return to the Utilities Menu.

SYSTEM TEST

(See Figure 4.5.)

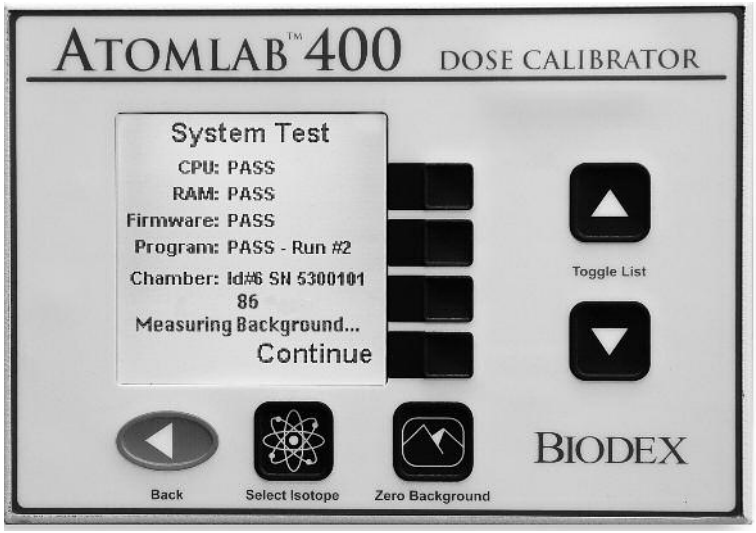

Figure 4.5. The System Test screen following power-up. If System Test is accessed while power is already ON, the "Measuring Background" line is not displayed.

The System Test runs an internal program to check function of the CPU, RAM, Firmware, Program and Chamber.

1. Press the <Screen Key> opposite the System Test prompt to access the System Test Results screen. The system will perform an internal test and report with pass or fail prompts for each parameter tested. The system test always shows a current chamber status.
2. Press the <Screen Key> opposite the Continue prompt to return to the Utilities Menu.

NOTE: *If any parameter should fail the system test, the system will display an error message. For example, if the chamber is not connected, the system will note "Error Code 7, Communication Error" at the bottom of the display screen. If a "Fail" message is displayed for the CPU, RAM, Firmware or Program tests, disconnect the power supply, reconnect the power and allow another system test to complete. If the tests still fail, contact the Biodex Medical Systems Service Department.*

CHANGE UNITS

(See Figure 4.6.)

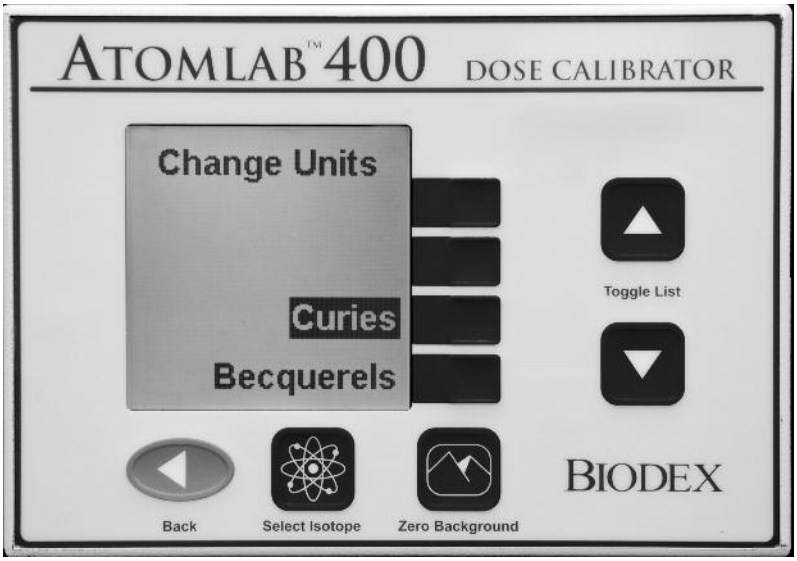

Figure 4.6. The Change Units function allows the user to select Curies (Ci) or Bequerels (MBq) as the units of measure.

The Change Units function allows the user to select Curies (Ci) or Becquerels (MBq) as the units of measure.

1. Press the <Screen Key> opposite the Change Units prompt to access the Change Units screen.
2. Press the <Screen Key> opposite the desired unit of measure. The system enables the selected unit type and returns to the Utilities Menu.

NOTE: *If you do not change units you must press <Back> to return to the Utilities Menu.*

DIAL VALUES

(See Figures 4.7 and 4.8.)

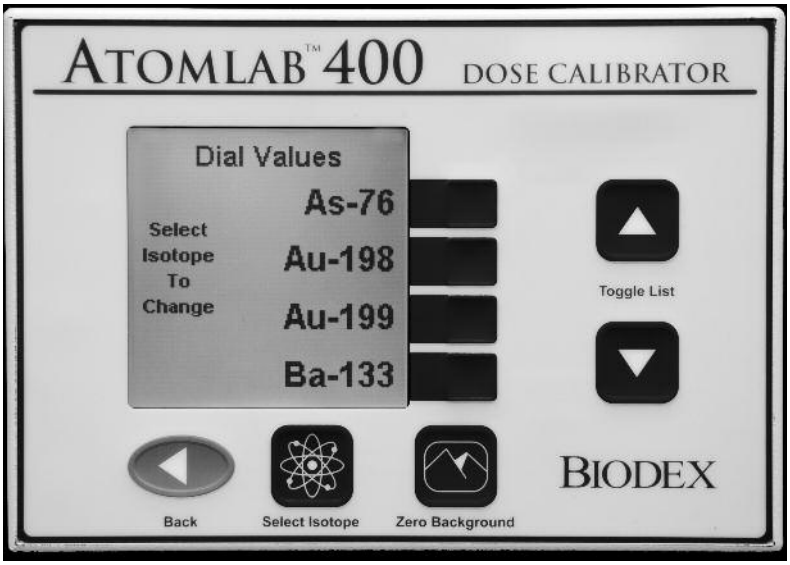

Figure 4.7. The Dial Values screen.

The Dial Values screens allow the user to change the dial setting for each isotope. The dial value is the calibration value for each isotope.

1. Press the <Screen Key> opposite the Dial Values prompt to access the Dial Values screens.
2. Use the <Toggle List> Keys to scroll though the isotope list until the desired isotope is displayed.
3. Press the <Screen Key> next to the desired isotope to display the dial value.
4. Use the <Toggle List> keys to increase or decrease the value displayed for the selected isotope.
5. Press <OK> to select the displayed isotope and value or <Cancel> to return to the original dial value displayed.
6. If you change the dial value and press <OK> a confirmation screen is displayed. Respond <OK> to the “Are you sure?” prompt to change the desired value. Press <Cancel> to return to the previously set dial value. If you pressed <OK> the system will now return to the Dial Values screen. From here you can select another isotope to change, or press <Back> to return to the Utilities Menu.

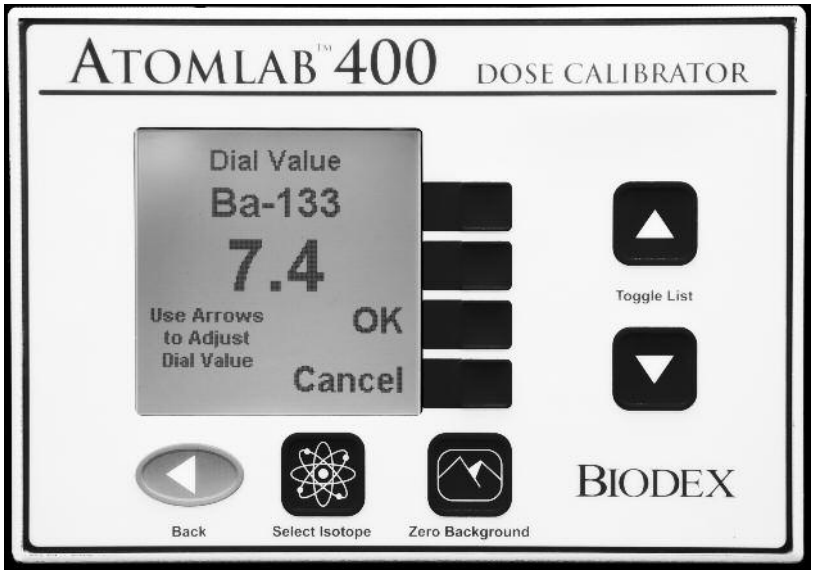

Figure 4.8. After selecting an isotope from the Dial Values screen, use the <Toggle Keys> to adjust the value.

FACTORY DEFAULTS

(See Figure 4.9.)

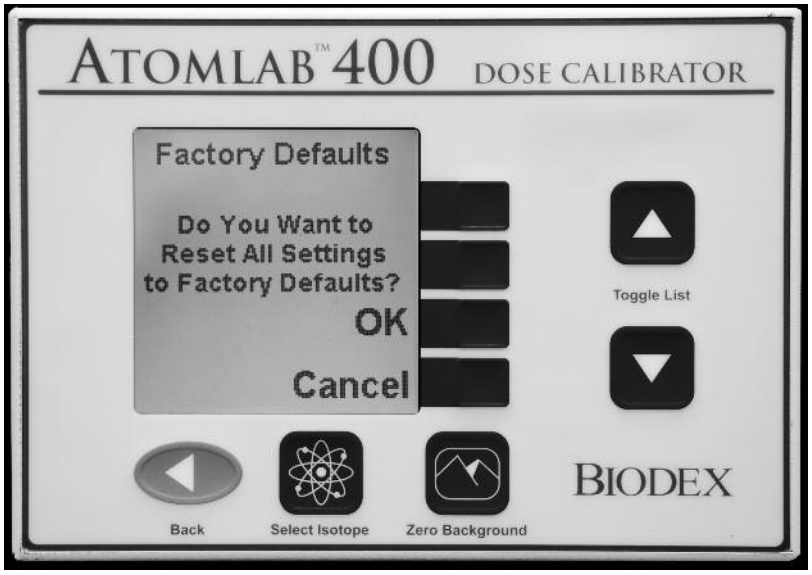

Figure 4.9. The user must confirm the process of resetting the Atomlab 400 to its factory defaults.

The Factory Defaults feature is used to **reset all settings** to their factory default values.

1. Press the <Screen Key> opposite the Factory Defaults prompt to access the Factory Defaults screen.
2. Press the <Screen Key> opposite the OK prompt to reset all settings to factory defaults, or press <Cancel> to return to the Utilities Menu without making changes.
3. If you elected to reset to the factory defaults, press <OK> to confirm the change. The system will reset all values to their factory defaults and return to the Utilities Menu.

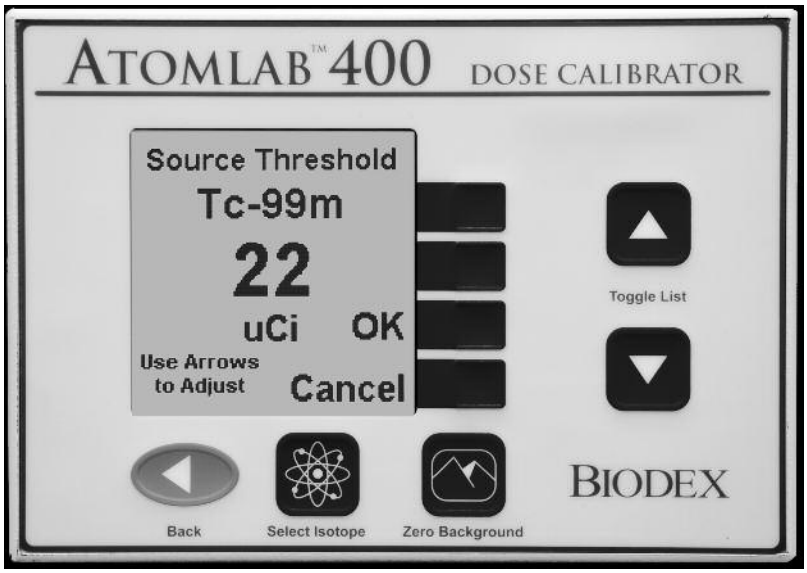

Figure 4.10.

SOURCE THRESHOLD

The Source Threshold value determines the system's response time. Activities above the threshold response time is quick. Below the threshold, response time is significantly slower.

1. To change the Source Threshold, press the <Screen Key> opposite the Source Threshold prompt.
2. Use the <Toggle List> arrows to increase or decrease the source threshold value, or press <Cancel> to return to the Utilities Menu without making changes.
3. If you have changed the source threshold value, press <OK> to confirm and return to the Utilities Menu.
4. To select a different isotope to use to set the system threshold level, press <Select Isotope> and then select the isotope desired. Use the <Toggle List> to increase or decrease the source threshold.

NOTE: *Changing any isotope's threshold changes the isotope threshold levels for all isotopes.*

NOTE: *The default threshold for Tc-99m is 20 µci. If a different isotope is selected, the activity level will be different for the threshold level.*

NOTE: *Unless you are reading activities less than 20 µCi* ***it is recommended to leave the threshold level for Tc-99m at 20 µCi.*** *The minimum threshold is 1 to 2 µCi for TC-99m, at this threshold setting the display activity readings have a higher fluctuation.*

CHAPTER 5:
ATOMLAB 400 DOSE CALIBRATOR DESCRIPTION

The Atomlab Dose Calibrators are used to measure the radioactivity of a known radioisotope. Their primary application is the measurement of the dose administered to a patient in nuclear imaging. The design for the Atomlab 400 incorporates unique electronics and software which meet stringent regulatory performance standards and provide fast and accurate results.

The Detector Unit uses an ionization chamber for radiation detection and an electrometer for ion current measurement. The chamber bias is generated with an electronic high voltage supply, eliminating the need for expensive battery changes.

The Display Unit communicates with the Detector Unit through a detector cable with RJ-12 connectors on both ends.

A RS-232 nine-pin serial port computer interface is available on the rear of the display. This interface will allow the user to send data and commands between the dose calibrator and a remote PC.The Atomlab 400 does not supply the software for the PC. If the host computer has no serial port, a USB/serial converter cable is available.

THE DETECTOR

The Atomlab Detector Unit is a well type ionization chamber capable of measuring activity as low as 0.01 μCi and as high as 40 curies of Tc-99m. The chamber is surrounded on all sides and on the bottom with .25-inch lead to both shield you from the source you are measuring and shield the dose calibrator from any ambient radiation.

THE CHAMBER

The well type chamber was carefully selected to provide a nearly "4 pi" measuring geometry which means that the radiation detector nearly surrounds the radionuclide. This allows the Atomlab Dose Calibrator to measure the activity of a sample no matter what its volume or shape, as long as it fits into the Chamber Well. This is necessary, for example, when measuring syringe doses when the volume is unimportant.

The chamber has electronics and the calibration built into it. Therefore, you can connect any Atomlab 400 display to a chamber and have a calibrated system.

CHAMBER WELL LINER

Placed within the well is a plastic liner to protect the chamber from contamination in the event of the source leaking during measurement. The dose calibrator should always be used with the well liner.

SOURCE HOLDER

Radioactive sources are measured by placing them within the well opening of the ionization chamber using the vial/syringe dipper. The vial/syringe dipper places the radioactive source in the location which is at the proper measurement geometry within the chamber. Samples contained within vials should be held in the bottom cup of the vial/syringe dipper. Samples within syringes should be placed in the syringe holder ring on the vial/syringe dipper. Sources should be orientated vertically in the source holder.

Sources should be placed in the dose calibrator well within 5 to 15 cm from the bottom of the chamber well, as measured without the well liner in place. The response of the dose calibrator varies +/-0.5% within this region.

CURRENT MEASUREMENT

The ionization current is measured by a microprocessor-controlled high impedance electrometer located within the base of the Detector Unit.

REAR PANEL

On the rear panel of the Detector Unit are the connectors for power and data communication with the Display Unit. The Detector Unit can be located up to 20 feet (6.09 meters) away from the Display Unit. The standard cable measures eight feet (2.43 meters) in length.

RESPONSE

The response of this type of ionization chamber has been carefully studied using radionuclides calibrated at the National Institute of Standards & Technology. The result is a well-defined energy response curve which is used to determine the calibration values for many different isotopes with high accuracy. Each chamber has been calibrated with a National Institute of Standards & Technology traceable source. The corresponding Calibration Value has been stored in the memory of the Detector Unit. After calibration, the chamber's accuracy is tested with several sources of differing gamma energies whose activity values are traceable to the National Institute of Standards & Technology.

THE DISPLAY UNIT

The Atomlab 400 Dose Calibrator Display Unit consists of function keys and an LCD display that allows you to make activity measurements. A built-in microprocessor executes commands input via the front panel keys and computes activity values from Detector data.

The Display Unit, with a molded plastic case housing the electronics, has been specifically designed to perform Activity Measurements in a laboratory setting. To allow easy fingertip control of the keys, the front panel slopes gradually, providing an optimum viewing angle. On the rear panel of the unit are the power and communication connectors, which remain out of the way as they are infrequently adjusted.

MEASUREMENT METHOD

The current from the chamber is measured in one of three ways, depending upon the order of magnitude of the current.

At low currents, the current from the chamber is collected upon a capacitor in the feedback loop of the electrometer whose capacitance is stable and measured to a high degree. Voltage measurements are made upon this capacitor many thousands of times per second. The time period between measurements is accurately calibrated. The second of two successive values is subtracted from the first, which yields the net voltage change of the capacitor over that short period of time. Thousands of successive differences are averaged over the course of one second in order to determine the chamber current during that second. After a sufficient rise in voltage, the charge on the capacitor is emptied, reducing the charge and voltage by a calibrated amount.

At medium currents, the capacitor will reach its maximum voltage value very quickly, and the capacitor must be emptied quite often. At these currents, the number of times the capacitor is emptied per unit time is used to calculate the current from the chamber.

At high currents, the capacitor cannot be emptied fast enough. Instead, the switch which controls when the capacitor is emptied is closed, and the electrometer is nulled. The value of the Digital to Analog Converter (DAC) which which is used to null the electrometer is used to determine the chamber current at high currents.

During calibration, multiple measurements are made at current values at which two modes of current measurement can be used effectively. These calibration measurements are used to set the calibration parameters of the medium and high current modes so as to meet the linearity required of the electrometer.

DISPLAY UNITS

When you set your dose calibrator to display Activity Values in Ci (Curies), the conventional system of units, either μCi, mCi or Ci, will be indicated next to the numeric display. The prefix micro or μ (10^{-6}), or milli or m $^{(10\text{-}3)}$ or Curies is automatically selected by the system's microprocessor.

For example, if the numeric value displayed is 12.03, and μCi is indicated, the activity will be 12.03×10^{-6} Ci or 0.00001203 Curies; if 63.9 is displayed and mCi indicated, the activity is 63.9×10^{-3} Ci or 0.0639 Curies.

In the same manner, when you set the dose calibrator to the international system of units, Becquerels, either MBq or GBq will be indicated, where the prefix M represents Mega (10^6) and G represents Giga (10^9).
The absolute measurement range of the Atomlab Dose Calibrator is from 0.01 μCi to 40.00 Ci of Tc-99m (and the equivalent in Becquerels).

For example, 12.03 μCi = .445 MBq and 63.9 mCi = 2.36 GBq. If the numeric display reads 0.445 and MBq is indicated, the activity value is 445,000 Becquerels; if 2.36 is displayed and GBq indicated, the activity is 2,360,000,000 Becquerels.

ROUTINE ISOTOPES

The Routine radioisotope (Isotope Selection) keys for the Atomlab 400 include: **Tc-99m, Tl-201, Co-57, Cs-137, I-131, In-111, Ga-67, Xe-133, I-123** and **Mo-99**. The **Co-57** and **Cs-137** keys are primarily used for accuracy and Constancy Tests while the Mo-99 key is used for the Moly Breakthrough Test.

Compare the displayed activity with the decayed calibrated activity (for an example of how to calculate a decayed activity see Appendix D: Decay Calculations. For a properly calibrated source above 100 μCi, the displayed value should be within a few percent of the decayed calibrated value.

NOTE: *If you do not have a Cs-137 source, use a calibrated Co-57 source and press the* ***Co-57*** *key to perform the above check.*

ATOMLAB DIAL VALUES

Equal activities of two different isotopes will generate different amounts of current in the ion chamber, due to differences in the energy and particle emitted by the isotopes. Dial Values are a means of calibrating the source activity measured for an isotope due to these differences in chamber current. The amount of current which is produced by a Co-60 source is defined as a dial value of 5.0; all other isotopes are defined relative to the Co-60 value. Co-60 was chosen as the defining isotope due to its high energy photon emission and long half-life. The high energy reduces the effect of container geometry (syringe, vial, etc) and the long half-life ensures that a single calibrated source can be used for many calibrations.

The Dial Value for certain isotopes have been directly measured using NIST calibrated sources provided from the NIST Standard Reference Materials program. These isotopes include Ga-67, Y-90, Tc-99m, Mo-99, In-111, I-125, I-131, Xe-133, and Tl-201. In addition the Cs-137 Dial Value has also been measured directly using a NIST calibrated source.

Using the measured chamber response for the isotopes listed above in conjunction with a Monte Carlo model of the ion chamber, chamber response curves have been generated. Using information on photon, electron and positron emission (from Table of Radioactive Isotopes, by Browne and Firestone verified with the Nuclear Data Center's Nudat 2.2 Database), calculated dial values have been generated for those isotopes for which direct measurement of the Dial Value was not possible.

CHAPTER 6: GLOSSARY

This glossary provides definitions for the most common terms relevant to the Atomlab Dose Calibrators.

Accuracy Tests
The test of a dose calibrator to see how close the displayed activity values are to the true values.

Averaging Period
The time the Atomlab takes to display a stable activity reading.

Background Correction
The function of the Atomlab, initiated by pressing the <Bkgnd> key, which stores a value for the ambient activity. This value is automatically subtracted from all subsequent activity measurements to compensate for the background activity level.

Becquerel (Bq)
The international unit of activity, corresponding to one dps (disintegration per second, or one nucleus decaying per second). The Atomlab displays activity values in units of MBq (million Bq) or GBq (billion Bq).

Calibration
The use of calibrated activity sources traceable to the National Institute of Standards & Technology to calibrate each Atomlab unit and verify the accuracy of the activity values it displays.

Calibration Value
The value set on the Dial Value Display to adjust the Atomlab to correctly respond to a particular radioisotope. See Response, Ionization Chamber.

Calicheck
A sleeve shield package to perform linearity tests on dose calibrators.

Chamber Bias
The high voltage applied to the chamber which causes ions in the argon gas to move to the collector electrode.

Constancy Check
Performing daily checks using a radioisotope with a long half-life to ensure that the activity values a dose calibrator displays is stable over a long period of time.

Decay Chart
A chart projecting how the activity of a source will decay over a period of time at specified time intervals.

Detector Unit
An Atomlab component housing the ionization chamber detector and the electrometer.

Dial Values
The section of the Atomlab Display using Increment/Decrement keys (▲ or ▼) and an associated isotope key, which allows the operator to enter any dial value possible on the display into the Atomlab program for an isotope.

Display Fluctuations
Displayed value changes without the removal or insertion of a source in the Chamber Well.

Display Unit
The Atomlab component incorporating the electronics, control keys and displays which perform and show activity measurements.

Dose Calibration
The verification of the activity of a radiopharmaceutical to be administered to a patient, corresponding to the radiation to be delivered to the body.

Electrometer
Measures the current in the ionization chamber, which is proportional to the activity of a source within the chamber.

Geometry Tests
The test of a dose calibrator to determine the variation in the displayed activity values due to the geometric configuration of the source's container (vial, syringe, etc.) and its location within the ionization chamber detector.

Ionization Chamber
A device which responds to the activity of a source by forming ion pairs which can be collected as a measure of the radioactivity.

Kit
A calibrated solution containing a compound labeled with a radionuclide such as Tc-99m (radiopharmaceuticals). From such kits doses are prepared to administer to patients to facilitate nuclear imaging.

L-Block Shield
A partially transparent radiation shield behind which doses can be prepared.

Linearity Tests
The test of a dose calibrator to determine the variation in the displayed activity values from the true ones over the measurement range of the instrument.

Lineator
A sleeve shield package to perform linearity tests on dose calibrators.

Moly Breakthrough Shield
Used in the Moly Breakthrough Test to shield the radiation of the Tc-99m in an eluent so that the activity of the Mo-99 can be measured.

Moly Break-through Test
Used to determine the percentage of parent Mo-99 remaining in the eluent containing the daughter Tc-99m radionuclide.

Molybdenum-99 (Mo-99)
The parent radionuclide which decays into the daughter Tc-99m, used to generate radiopharmaceuticals.

NIST
National Institute of Standards & Technology, whose activities include maintaining radioactive material standards.

NORMALIZED READING
This is the measurement that pre-calibration and post-calibration factors are applied to for determining the calculated activity.

NRC
Nuclear Regulatory Commission, which is the agency of the Federal Government which regulates radioactive materials.

Range Selection
The Atomlab unit automatically selects which range of Display units (μCi, mCi, Ci, MBq or GBq) to be used for the Activity Display to show activity values with the most significant number of digits.

Response, Ionization Chamber
The variation of the ion current collected by an ionization chamber because of individual decay processes associated with different radioisotopes. Calibration Values are required to adjust the output of the electrometer for each radioisotope to compensate for this variation in response, thereby ensuring accuracy over the entire range of commonly used radioisotopes.

Sleeve Shield
A method of performing linearity tests on a dose calibrator by encircling a single source with leaded sleeves of varying thickness, thereby reducing the activity the dose calibrator measures by a known amount. Comparison of the expected and actual activity values constitutes the test of linearity.

Source Decay
A method of performing linearity tests on a dose calibrator by measuring the initial activity of a source, accurately calculating its decayed activity at prescribed time intervals, and making activity measurements at those time intervals. Comparison of the calculated and actual activity values constitutes the test of linearity.

Traceability
Refers to using sources for calibrating a dose calibrator whose activities can be traced to the National Institute of Standards & Technology.

APPENDIX A:
ATOMLAB DOSE CALIBRATOR
TROUBLE-SHOOTING PROCEDURES

Should it appear that your Atomlab Dose Calibrator is not functioning properly, the procedures explained in this appendix, should allow you to determine whether a problem does indeed exist and what steps can be taken to correct the difficulty.

Should you encounter any of the problems discussed in the following sections, immediately perform the accompanying steps to ascertain whether your dose calibrator requires servicing. If you conclude that it does, contact the Biodex Customer Service Department at 1-800-224-6339 for further instructions.

The following problems are described in this appendix.

- System will not Power Up
- Fluctuations in Activity Measurement
- Unexpected Readings
- Important Notes about System Errors

SYSTEM WILL NOT POWER UP

If your Atomlab Dose Calibrator fails to power up, perform the following steps, proceeding to the next step only if the current one fails to remedy the problem:

Procedure

1. Remove the power cord from the electrical outlet. Remove the other end of the Power Cord from the receptacle on the power pack.

2. Re-insert the power cord into the receptacle and then plug the Power Cord back into the power pack. The dose calibrator should restart and the display will boot up after several seconds.

3. Remove the power cord from the outlet and verify that the voltage of the outlet is correct. If not, repair the outlet or find another outlet that provides the required voltage. Re-insert the power cord and turn the power back ON. The power pack converts wall power from 100V to 240 V to the correct voltage for the dose calibrator.

   If your system still will not power up, call the Biodex Customer Service Department.

FLUCTUATIONS IN ACTIVITY MEASUREMENT

When the system is displaying activity for the more common isotopes, the electrometer continually averages the data it receives from the detector. This ensures, for most readings, a stable Activity Display.

After you insert an isotope into the Detector and select the properly calibrated key, the display may vary at low activity values as the system acquires the new data. After a short time the Activity Display will stabilize, with expected fluctuations described below. If the display continues to fluctuate, and you have verified it is not because of a high Calibration Value, consult Biodex Customer Service Department.

Display Fluctuations For High Calibration Values

For some isotopes which require a high Calibration Value, you may observe fluctuations of ±0.5 μCi or more. Keep in mind that the Calibration Value for an Isotope is related to gain of the electrometer, or by what factor the electrometer has to amplify the signal from the detector. The Calibration for Tc-99m is 37.1, and a reading of 10 μCi for Tc-99m is equivalent to 160 to 180 femtoamps of current measured by the electrometer. High Calibration Values impact gains so that the electrometer amplifies inherent noise to a greater degree. Thus, greater fluctuations are observed in the Activity Display.

For instance, the Calibration Value for Co-60 is 5.0. The fluctuation due to noise probably would not be noticeable (±0.01 μCi). The fluctuation due to noise for Tc-99m (37.1) is approximately ±0.05 μCi. For an isotope requiring a Calibration Value of 500 (for P-32 it is 530) the fluctuation will be ±0.5 μCi or more.

Mo-99 Fluctuations

The Atomlab Dose Calibrator begins averaging display data the moment you press the Mo-99 key (Calibration Value =175). This means that at first the fluctuations will seem relatively high before gradually decreasing. This is why the Atomlab Dose Calibrator provides the 30-second countdown. In addition, the relatively high Calibration Value means the fluctuation due to inherent noise will be slightly higher than for the other common isotopes. Again, these fluctuations are to be expected and do not require any action on your part.

UNEXPECTED READINGS

If for some reason you suspect that the reading on the Activity Display is inaccurate, ensure that the Calibration Value for the proper Isotope Selection key is correct.

Chamber Service

⚠ ***CAUTION****: Only qualified service personnel should remove the chamber cover. There is an electrical shock hazard. Components under cover operate at 350 volts. The chamber bias supply capacitors require at least two weeks, with power disconnected, to discharge to less than 50 volts.*

⚠ ***ATTENTION:*** *On ne doit confier qu'à un personnel d'entretien qualifié le soin de déposer le couvercle de la chambre d'ionisation. Il y risque de danger électronique. Les composants sous le couvercle fonctionnent sous une tension d'environ 350 V. La chambre d'ionisation est dotée de condensateurs qui nécessitent au moins deux semaines d'alimentation débranchée pour se décharger à moins de 50 V.*

TROUBLE SHOOTING GUIDE

Problem	Probable Cause	Solution
No Power	No AC line input Check for attached AC line cord	Check outlet for AC Reconnect line cord
	Check connection of 15VDC Power pack on back of display	Reset power pack jack
	Check output of power pack Should be 15VDC at 1.6 Amp max	Contact Biodex
No Display	See power problems above	
	Brightness too low	Adjust Brightness pot R 15 on display board (MOD 400)
	Reseat ribbon cable between display board and LCD display	Contact Biodex
No Chamber Found	Comm failure between display and chamber	Reseat display/chamber interface cable
	System locked up	Cycle AC power
	Bad cable	Replace interface cable
Low Readings	Incorrect dial value used	Confirm and reinstall correct dial value
	Incorrect unit of measurement	Confirm Bequerel or Curie as unit of measurement
	Low chamber gas pressure	Contact Biodex

APPENDIX B:
ATOMLAB DISPLAY DIAGNOSTICS FOR 400/500 SERIES

OVERVIEW

The nine button black & white Atomlab 400 and color touch screen Atomlab 500 for the new generation of AtomLab products have built-in boot-up self-diagnostics, along with real-time monitoring of the detector statuses. The detectors themselves have real-time self tests, the results of which are reported back to the display approximately once per second. Dose Calibrator chambers and Well Counters are the two types of detectors supported.

The results of the display module's self-test are displayed during the display's power-up, as well as on-demand, shown on the System Test screen under Utilities, in the upper section of the display results. In addition, during normal operation detector status changes are handled by the display, reported on screen with a popup screen and audio tone alert, and actions taken based on the severity of the reported status.

The System Test screen displayed results are divided into two sections:
- Upper half is the display module's details (static result from boot-up)
- Lower half lists diagnostic and status results for each identified detector, up to 7 on an Atomlab 500. Dynamically updated in real-time, about once/second

Real-Time Operating Detector Status Changes

During the course of normal operation, detectors report their status constantly to the display unit, including any detectable error conditions. The status reports are available as long as the power to the display remains on, the detectors stay connected, and the system is not in a severe fault state (communication error). So this means even if the detectors are not being used, or the display is blanked from the screen saver, the detectors are still communicating and being monitored.

For each error status newly reported, a Detector or Chamber Status error reporting screen will appear with a 3 beep audio tone to alert the user. An error code will be displayed with it's brief description. If WARNING is displayed next to the code, it indicates the chamber is still usable. If FAIL is displayed next to the code, the chamber will automatically be dropped from being selectable by the user. For an Atomlab 500 with multiple chambers, the next available detector will automatically be selected. If there are no available detectors, the activity readings displayed will be dashed out and activity screen will indicate no available chamber, or chamber error.

For “Chamber Leaking Gas” or “Chamber Gas Low” warnings, there is a 24 hour reminder warning implemented. If either of these warnings is in effect for a connected chamber, every 24 hours the Detector or Chamber Status screen will display with this warning code and description. All the 24 hour reminders are scheduled to appear 8AM, and only if 4 hours elapsed since the warning was first detected and displayed.

System Test Screen
The System Test screen is divided into two sections, where the upper half of the screen shows diagnostics of the display module unit itself from the boot-up self-diagnostics, and the lower half shows diagnostics relating to the detectors, dynamically updated while the detectors are connected and communicating.

Display Module Diagnostics Display (upper half)
There are three fields displayed in this section:

CPU Functions – result of testing the main processor’s basic functionality (PASS/FAIL)

RAM Tests – results of performing 4 different tests on the integrity of the main memory chip, 8 MB of storage: stuck bit test for 0 and 1, alternating bit (cross over) test, and an addressing test

Firmware Check – displays the results of checking the CRC’s of 3 different program loaded in flash memory: the Boot program, Main #1 program, and Main #2 program

Program Load – displays the results of checking the Boot configuration in flash memory (CRC’ed), and if it was required to changed the default program selected to load

Following is the possible displayed values:

CPU Functions

PASS {all tests passing}
FAIL {at least 1 of the tests of the processor detected an error}

RAM Tests

PASS {all 4 memory tests passing}
FAIL – Code: n {a memory test failed, see values below}

n=1: Stuck Bit test for 0 failed
n=2: Stuck Bit test for 1 failed
n=3: Alternating Bit test failed
n=4: Addressing test failed

Firmware Check

PASS {all 3 programs were read and verified using CRC-16}
WARN – Code: n {Error detected in Boot Program, see values below}
FAIL – Code: n-n-n {Error detected in Boot, Main #1, and/or Main #2}

n=0: no error detected
n=1: Parameter Block inconsistency
n=2: Parameter Block CRC-16 error detected
n=3: Program CRC-16 error detected

Program Load

PASS – Loaded Program #n {n is 1 or 2}
WARNING – Code n-n {error detected, see values below}

1-0: Boot Configuration inconsistency
2-0: Boot Configuration CRC-16 error detected
0-1: the default program (#1 or #2) was invalid for some reason, so the alternate program had to be loaded
1-1: combined errors: Boot Configuration inconsistency and invalid default
2-1: combined errors: Boot Configuration CRC-16 error and invalid default

DETECTOR DIAGNOSTICS DISPLAY (LOWER HALF)

There are several properties of a Dose Calibrator chamber monitored and measured. The results are reported as a coded value, with an associated description. Space on the display is tight to accommodate up to 7 detectors, so if there's only 1 error in effect, we display the associated description. If there are multiple errors, we display only the codes. Here is the list of error codes, their class, and their description for Dose Calibrators:

Error Code	Class	500 Description	400 Description
Code 2	FAIL	Firmware Checksum	Firmware Checksum
Code 3	FAIL	Electrometer Needs Recalibration	Electrometer Recalibration
Code 4	FAIL	EEPROM Data Corrupt	EEPROM Data Corrupt
Code 5	WARNING	Chamber Gas Low, Correctable	Chamber Gas Low - OK
Code 6	FAIL	Chamber Gas Too Low to Use	Chamber Gas Too Low
Code 7	FAIL	Communications Error	Communications Error
Code 8	FAIL	Chamber Bias Voltage Anomaly	Chamber Voltage
Code 9	FAIL	Electrometer Monitor Voltage Anomaly	Electrometer Voltage
Code 10	WARNING	OverRange Chamber Reading (Too High)	OverRange Reading

Following is the display status displays for the Dose Calibrators:

Warming Up	{chamber is in a power warm-up state}
Initializing Background	(Count Down)
	{initial background reading/calc is in effect}
PASS –	no reported problems
	{no errors in effect, ready for measuring activity}
WARNING n -	<description> {1 error code}
WARNING n-n-n	{2 or more error codes may be present}
FAIL: n -	<description>
FAIL: n-n-n	{2 or more error codes may be present}

Warnings are errors flagged by the self tests, but not considered permanent or serious enough to not use the reported activity measurements.

Failures (FAIL) are considered serious enough to not use the chamber for any activity measurements. The chamber will automatically be taken offline by the system, no longer selectable.

CHAMBER ERROR CODE DESCRIPTIONS

Code 2, Firmware Checksum

FAIL - The chamber's firmware has a checksum pre-calculated and stored, and it's verified during chamber power up. This error indicates the checksum calculated failed to match the checksum stored. Continuing to operate the chamber would be at risk. The chamber should be serviced.

Code 3, Electrometer Needs Recalibration

FAIL - On startup, this error code is set if any of the following numbers don't exist or fail a sanity check:
- Activity calibration factor
- ump, ubp (factors for linearity corrections for higher gains)
- monitor channel scaling factor
- any of the four linearity correction constants

The chamber should be serviced.

Code 4, EEPROM Data Corrupt
FAIL - The chamber's stored data has a checksum pre-calculated and stored, and it's verified during chamber power up. This error indicates the checksum calculated failed to match the checksum stored for the appropriate stored data. Continuing to operate the chamber would be at risk. The chamber should be serviced.

Code 5, Chamber Gas Low, Correctable
WARNING - If grams of Argon drops more than 5% of the initial factory measured value, this error code is set. There is no correction done when this error code is active.

Code 6, Chamber Gas Too Low to Use
FAIL - If the grams of Argon drops more than 10% of the initial factory measured value, this error code is set. There is no correction done when this error code is active. The chamber should be serviced.

Code 7, Communications Error
FAIL – This error code is set when repeated attempts of the display unit to communicate with a chamber failed. Once this error code is set, the display unit will no longer attempt to communicate with the chamber. This could be caused from a bad chamber or a bad or disconnected cable between the chamber and the display unit.

Code 8, Chamber Bias Voltage Anomaly
FAIL - Chamber voltage bias must be out of the range of 325V - 375V for this error code to be set. The chamber should be serviced.

Code 9, Electrometer Monitor Voltage Anomaly
FAIL - Electrometer voltage must be out of the range of 2.375V - 2.55V for this error code to be set. The chamber should be serviced.

Code 10, OverRange Chamber Reading (Too High)
WARNING – The detected chamber activity reading has exceeded the capability of what the chamber can accurately measure. This error code should be only temporary, for the time a very high reading is being measured. If this occurs without an explainable cause, the chamber may be faulty and should be serviced.

APPENDIX C:
ATOMLAB 400 DOSE CALIBRATOR SPECIFICATIONS

OVERVIEW
This appendix provides the physical and operating specifications of your Atomlab 400 Dose Calibrator.

MEASUREMENT RANGE
For Tc-99m, 0.01 μCi to 40 curies, auto-ranging.

DISPLAY RANGES
Units are user selectable:

Ci		Bq	
00.00—1999	μCi	00.00—19.99	MBq
2.00—19.99	mCi	20.0—199.	MBq
20.0—199.9	mCi	200—1999	MBq
200—9999	mCi	2.00—399.9	GBq
10.00—40.00	Ci	10.0—1500.0	GBq

RESPONSE TIME
Auto Selection: Display updates once per second.
1-2 seconds >200 microcuries Tc
3 seconds >20 microcuries Tc
50-100 seconds <20 microcuries Tc

NOTE: *Response time for activity of less than 20 microcuries can be decreased by reducing the measurement threshold. Reducing the measurement threshold decreases response time at the cost of higher fluctuation.*

NOTE: *All activities listed in specifications are for Tc-99m; for the specifications concerning other isotopes, please convert to Tc-99m equivalent. The Tc-99m equivalent of an isotope can be found by multiplying the source activity by the Tc-99m dial value, then dividing by the isotope dial value. The Tc-99m equivalent is the activity of a Tc-99m source which would produce the same current as the isotope source when placed in the well chamber.*

NOTE: *Unless you are reading activities less than 20 μCi* ***it is recommended to leave the threshold level for Tc-99m at 20 μCi.*** *The minimum threshold is 1 to 2 μCi for TC-99m, at this threshold setting the display activity readings have a higher fluctuation.*

ACCURACY

Overall accuracy of activity determination for isotopes Co-57, Co-60, Ga-67, Tc-99m, In-111, I-131, Ba-133, Cs-137, and Tl-201, using the factory set calibration values are within 3% or 0.3 microcuries, whichever is greater.

NOTE: *Intercomparison of calibrated sources and the Atomlab 400 requires combining the uncertainties of both the Atomlab 400 and the calibrated source to determine expected agreement.*

DETECTOR LINEARITY

Within 1% or 0.2 μCi, whichever is greater.

ELECTROMETER LINEARITY

Within 1% or 0.2 μCi, whichever is greater.

ELECTROMETER ACCURACY

Within 1% or 0.2 μCi, whichever is greater.

STABILITY

Short term (24 hours):	within 0.3% above one mCi, exclusive of background.
Long term (one year):	within 1%.

NOISE FLUCTUATIONS

Display Fluctuations	Activity Range
<1 digit after 1-2 seconds	>199.9 microcuries
<+/- 4 after 3 seconds, +/-2 after 10 seconds	>19.99 microcuries
<+/-4 after 50-100 seconds	0.01 to 19.9 microcuries

ENERGY RANGE

25 keV to 3 MeV

ISOTOPE SELECTION

Ten Routine isotope selections: Tc-99m, Tl-201, Co-57, Cs-137, I-131, In-111, Ga-67, Xe-133, I-123 and Mo-99.

The unit displays readings in uCi, mCi, Ci, MGq or GBq.
Dial values can be reset for new calibration values.
The Mo-99 key is calibrated for Mo-99 assay in a shielded vial of Tc-99m.
The Atomlab 400 provides a 30-second countdown.
Alphabetical List
Seven settable selections
Two user programmable selections: New Isotope 1 and 2.

CALIBRATION VALUE DISPLAY
Up and down arrow control with dial values from 0.0 to 999.9.

DETECTOR TYPE
Well-type pressurized ionization chamber, with Argon filled gas. Replaceable plastic liner included. Dimensions are:

Well opening:	2.75 in. (7 cm)
Well depth:	10.50 in. (26.7 cm)
Well opening with liner:	2.5 in. (6.4 cm)
Well depth with liner:	10.25 in. (26 cm)

Detector Shield
.25 in. (6 mm) lead surrounding ionization chamber, with top well opening.

Chamber Bias
355 +/-5 volts

ENVIRONMENTAL OPERATING CONDITIONS

Temperature:	0 to 40°C
Humidity:	0 to 95% rh, non-condensing

For optimum performance, the Atomlab 400 should be operated in a normal laboratory environment where the temperature and humidity are maintained for normal human comfort and the ambient radiation level is low and constant.

PHYSICAL DATA

	Display Unit	Detector Unit
Size:	6.75" w x 5" H x 6" d (17.15 x 12.7 x 15.24 cm)	6" dia x 15.5" h (15.24 x 39.37 cm)
Weight:	3.6 lb (1.64 kg)	38 lb (17.3 kg)

POWER
APS (Advanced Power Solutions) Power Supply for Medical Use.
Model # APS22ES-150160

Line Voltage
100 to 240 VAC, 0.6 – 0.3 Amp

Line Frequency
50/60 Hz
Detachable line cord. Built-in EMI filter and transient suppression.

NOTE: *Before inserting or removing connectors turn system power OFF.*

DETECTOR CABLE
Length
Standard: 8 ft (2.438 m); custom cable lengths available up to 20 meters

Conductors
Six total: two for power, two for chassis ground, two for serial data.

Connectors
RJ-12

Auxillary Port
RS-232 connector

GRAPHIC DISPLAY
160 x 160 pixels, monochrome LCD display, 2.5" x 2.5" in size

CALIBRATOR CONSTANCY ISOTOPES
Co-57 and Cs-137 E-vials are normally used for accuracy and constancy checks.

NOTE: *Medical electrical equipment needs special precautions regarding EMC and needs to be installed and put into service according to the EMC information provided in the accompanying documents; Appendeix H (EMC chart). Portable and mobile RF communications equipment can affect medical electrical equipment.*

NOTE: *The use of accessories, and cables other than those specified, with the exception of cables sold by manufacturer, may result in increased or decreased immunity of the equipment or system.*

ELECTROMECHANICAL COMPATIBILITY
As per CISPR 11 complies with Group 1 Class B requirements

ETL Listed
Electrical Equipment, Laboratory Use;
Part 1, General Requirements for Safety conforms to UL 60601-1, CAN/CSA C22.2 No: 601-1-M90, IEC 601-1, IEC 60601-1-1-4 and IEC 60601-1-2.

Intertek

CE 0413

Authorized European Community Representative:

EC REP

Emergo Europe
Molenstraat 15
2513 BH, The Hague
The Netherlands

APPENDIX D:
DECAY CALCULATIONS

OVERVIEW

This appendix provides methods of performing radioisotope decay calculations.

The first section provides two methods of performing Decay Calculations, the second section provides the Decay Factor Chart, and the third section provides an explanation of how the procedures used in the first section, and the Decay Factor Chart in the second section, are generated.

DECAY CALCULATION METHODS – CALCULATOR METHOD

If you are using a calculator with the Y^X function, perform the following:

1. Measure the current activity of the radioisotope (A_0), which can be compared to the decayed calculated activity.

2. Look up the half life $T_{1/2}$ of the radioisotope in Appendix E. Note the time units.

3. $T_{1/2}$ = Half life of the isotope
   t = Elapsed Time
   A = Current Activity
   A_0 = Activity at the time of calibration

4. Calculate $A = A_0 \times 2^{(-t/T_{1/2})}$

5. Calculate the elapsed time (t) in the same units as the ($T_{1/2}$) that will elapse between when the calibrated activity measurement was made and when you wish to know what the decayed activity of your radioisotope will be.

Sample Calculation

The following is a calculation of the decayed activity of Tc-99m, with an initial activity of 43 *m*Ci, after 53 minutes:

6. A_0 = 43 *m*Ci.

7. For Tc-99m, $T_{1/2}$ = 6.007 h.

8. Elapsed t = 53 min x $\frac{1 \text{ hr}}{60 \text{ min}}$ = 0.8833 hr

9. $A = A_0 \times 2^{(-t/T_{1/2})}$
   $A = 43\ mCi \times 2^{(-0.8833/6.007)}$
   $A = 43\ mCi \times 2^{(-0.147045)}$
   $A = 43\ mCi \times 0.903$
   $A = 38.83\ mCi$

ALTERNATE DECAY CALCULATION METHOD

If you are using a calculator with the Y^x function, perform the following:

1. Measure the current activity of the radioisotope (A_0), which can be compared to the decayed calculated activity.

2. Look up half life ($T_{1/2}$) of the radioisotope in Appendix E. Note the time units.

3. $T^{1/2}$ = Half life of the isotope
   t = Elapsed Time
   A = Current Activity
   A_0 = Activity at the time of calibration
   n = elapsed time / half life

4. Calculate $A = A_0 / 2^n$

5. Calculate the elapsed time (t) in the same units as the ($T_{1/2}$) that will elapse between when the calculated activity measurement was made and when you wish to know what the decayed activity of your radioisotope will be.

Sample Calculation

6. A_0 = 43 mCi.

7. For Tc-99m, $T_{1/2}$ = 6.007 h.

8. Elapsed t = 53 min $\times \frac{1\ hr}{60\ min}$ = 0.8833 hr

9. Replace equation with following:
   $A = A_0 / 2^n$
   $A = 43\ mCi / 2^{(0.8833/6.007)}$
   $A = 43\ mCi / 2^{(0.1470451)}$
   $A = 43\ mCi / 1.1072992$
   $A = 38.83\ mCi$

DECAY FACTOR METHOD

The following method is used to perform radioisotope decay calculations using a calculator without the $\mathbf{e}^x$ function:

1. Measure the current activity A_i of the radioisotope.

2. Look up half life ($T_{1/2}$) of the radioisotope in Appendix E. Note the time units.

3. Calculate the time (**t**), in the same units as ($T_{1/2,}$) that will elapse between when the activity measurement was made and when you wish to know what the decayed activity of your radioisotope will be.

4. Calculate **t** / $T_{1/2}$ in terms of N + R, where N is an integer (0, 1, 2, etc.) and R is less than 1.

5. Look up X_n (N) in Table 1. on page D-4.

6. Look up X_r (R) in the Decay Factor Chart.

7. Calculate $A_f = A_i \times X_n$ (N) x X_r (R).

Sample Calculation

The following is a calculation of the decayed activity of Tc-99m, with an initial activity of 43 mCi, after 32.5 hours:

1. A_i = 43 *m*Ci.

2. For Tc-99m, $T_{1/2}$ = 6.007 h.

3. **t** = 32.5 h.

4. **t** / $T_{1/2}$ = 32.5 h / 6.007 = 5.410. N = 5, R = 0.410.

5. From Table 1, X_n (5) = 0.03125.

6. From the Decay Factor Chart, the **.41** row and the **.000** column, X_r (.410) = .75262.

7. $A_f = A_i \times X_n (N) \times X_r (R) = 43$ *m*Ci x (0.03125) x (.75262) = 1.01 *m*Ci.

N	$X_n (N) = 2^{-N}$
0	1
1	0.5
2	0.25
3	0.125
4	0.0625
5	0.03125
6	0.01563
7	0.007813
8	0.003906
9	0.001953
10	0.000977

Table 1

DECAY FACTOR CHART

X_r (R), where $\mathbf{R = t / T_{1/2}}$ (0.000 to 0.499)

R	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
.00	1.00000	.99931	.99861	.99792	.99723	.99654	.99585	.99516	.99447	.99378
.01	.99309	.99240	.99172	.99103	.99034	.98966	.98897	.98829	.98760	.98692
.02	.98623	.98555	.98487	.98418	.98350	.98282	.98214	.98146	.98078	.98010
.03	.97942	.97874	.97806	.97739	.97671	.97603	.97536	.97468	.97400	.97333
.04	.97265	.97198	.97131	.97063	.96996	.96929	.96862	.96795	.96728	.96661
.05	.96594	.96527	.96460	.96393	.96326	.96259	.96193	.96126	.96059	.95993
.06	.95926	.95860	.95794	.95727	.95661	.95595	.95528	.95462	.95396	.95330
.07	.95264	.95198	.95132	.95066	.95000	.94934	.94868	.94803	.94737	.94671
.08	.94606	.94540	.94475	.94409	.94344	.94278	.94213	.94148	.94083	.94017
.09	.93952	.93887	.93822	.93757	.93692	.93627	.93562	.93498	.93433	.93368
.10	.93303	.93239	.93174	.93109	.93045	.92980	.92916	.92852	.92787	.92723
.11	.92659	.92595	.92530	.92477	.92402	.92338	.92274	.92210	.92146	.92083
.12	.92019	.91955	.91891	.91828	.91764	.91700	.91637	.91573	.91510	.91447
.13	.91383	.91320	.91257	.91193	.91130	.91067	.91004	.90941	.90878	.90815
.14	.90752	.90689	.90626	.90563	.90501	.90438	.90375	.90313	.90250	.90188
.15	.90125	.90063	.90000	.89938	.89876	.89813	.89751	.89689	.89627	.89565
.16	.89503	.89440	.89379	.89317	.89255	.89193	.89131	.89069	.89008	.88946
.17	.88884	.88823	.88761	.88700	.88638	.88577	.88515	.88454	.88393	.88332
.18	.88270	.88209	.88148	.88087	.88026	.87965	.87904	.87843	.87782	.87721
.19	.87661	.87600	.87539	.87478	.87418	.87357	.87297	.87236	.87176	.87115
.20	.87055	.86995	.86934	.86874	.86814	.86754	.86694	.86634	.86574	.86514
.21	.86454	.86394	.86334	.86274	.86214	.86155	.86095	.86035	.85976	.85916
.22	.85857	.85797	.85738	.85678	.85619	.85559	.85500	.85441	.85382	.85323
.23	.85263	.85204	.85145	.85086	.85027	.84968	.84910	.84851	.84792	.84733
.24	.84675	.84616	.84557	.84499	.84440	.84382	.84323	.84265	.84206	.84148
.25	.84090	.84031	.83973	.83915	.83857	.83799	.83741	.83683	.83625	.83567
.26	.83509	.83451	.83393	.83335	.83278	.83220	.83162	.83105	.83047	.82989
.27	.82932	.82874	.82817	.82760	.82702	.82645	.82588	.82531	.82473	.82416
.28	.82359	.82302	.82245	.82188	.82131	.82074	.82017	.81960	.81904	.81847
.29	.81790	.81734	.81677	.81620	.81564	.81507	.81451	.81394	.81338	.81282
.30	.81225	.81169	.81113	.81057	.81000	.80944	.80888	.80832	.80776	.80720
.31	.80664	.80608	.80552	.80497	.80441	.80385	.80329	.80274	.80218	.80163
.32	.80107	.80051	.79996	.79941	.79885	.79830	.79775	.79719	.79664	.79609
.33	.79554	.79499	.79443	.79388	.79333	.79278	.79223	.79169	.79114	.79059
.34	.79004	.78949	.78895	.78840	.78785	.78731	.78676	.78622	.78567	.78513
.35	.78458	.78404	.78350	.78295	.78241	.78187	.78133	.78079	.78025	.77970
.36	.77916	.77862	.77809	.77755	.77701	.77647	.77593	.77539	.77486	.77432
.37	.77378	.77325	.77271	.77218	.77164	.77111	.77057	.77004	.76950	.76897
.38	.76844	.76791	.76737	.76684	.76631	.76578	.76525	.76472	.76419	.76366
.39	.76313	.76260	.76207	.76154	.76102	.76049	.75996	.75944	.75891	.75838
.40	.75786	.75733	.75681	.75628	.75576	.75524	.75471	.75419	.75367	.75315
.41	.75262	.75210	.75158	.75106	.75054	.75002	.74950	.74898	.74846	.74794
.42	.74742	.74691	.74639	.74587	.74536	.74484	.74432	.74381	.74329	.74278
.43	.74226	.74175	.74123	.74072	.74021	.73969	.73918	.73867	.73816	.73765
.44	.73713	.73662	.73611	.73560	.73509	.73458	.73408	.73357	.73306	.73255
.45	.73204	.73154	.73103	.73052	.73002	.72951	.72900	.72850	.72799	.72749
.46	.72699	.72648	.72598	.72548	.72497	.72447	.72397	.72347	.72297	.72247
.47	.72196	.72146	.72096	.72047	.71997	.71947	.71897	.71847	.71797	.71747
.48	.71698	.71648	.71598	.71549	.71499	.71450	.71400	.71351	.71301	.71252
.49	.71203	.71153	.71104	.71055	.71005	.70956	.70907	.70858	.70809	.70760

DECAY FACTOR CHART

X_r (R), where $\mathbf{R = t / T_{1/2}}$ (0.500 to 1.0)

R	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
.50	.70711	.70662	.70613	.70564	.70515	.70466	.70417	.70368	.70320	.70271
.51	.70222	.70174	.70125	.70076	.70028	.69979	.69931	.69882	.69834	.69786
.52	.69737	.69689	.69641	.69592	.69544	.69496	.69448	.69400	.69352	.69304
.53	.69255	.69208	.69160	.69112	.69064	.69016	.68968	.68920	.68873	.68825
.54	.68777	.68729	.68682	.68634	.68587	.68539	.68492	.68444	.68397	.68349
.55	.68302	.68255	.68207	.68160	.68113	.68066	.68019	.67971	.67924	.67877
.56	.67830	.67783	.67736	.67689	.67642	.67596	.67549	.67502	.67455	.67408
.57	.67362	.67315	.67268	.67222	.67175	.67129	.67082	.67036	.66989	.66943
.58	.66896	.66850	.66804	.66757	.66711	.66665	.66619	.66573	.66526	.66480
.59	.66434	.66388	.66342	.66296	.66250	.66204	.66159	.66113	.66067	.66021
.60	.65975	.65930	.65884	.65838	.65793	.65747	.65702	.65656	.65611	.65565
.61	.65520	.65474	.65429	.65384	.65338	.65293	.65248	.65203	.65157	.65112
.62	.65067	.65022	.64977	.64932	.64887	.64842	.64797	.64752	.64707	.64662
.63	.64618	.64573	.64528	.64483	.64439	.64394	.64349	.64305	.64260	.64216
.64	.64171	.64127	.64082	.64038	.63994	.63949	.63905	.63861	.63816	.63772
.65	.63728	.63684	.63640	.63596	.63552	.63508	.63464	.63420	.63376	.63332
.66	.63288	.63244	.63200	.63156	.63113	.63069	.63025	.62982	.62938	.62894
.67	.62851	.62807	.62764	.62720	.62677	.62633	.62590	.62546	.62503	.62460
.68	.62417	.62373	.62330	.62287	.62244	.62201	.62157	.62114	.62071	.62028
.69	.61985	.61942	.61900	.61857	.61814	.61771	.61728	.61685	.61643	.61600
.70	.61557	.61515	.61472	.61429	.61387	.61344	.61302	.61259	.61217	.61174
.71	.61132	.61090	.61047	.61005	.60963	.60921	.60878	.60836	.60794	.60752
.72	.60710	.60668	.60626	.60584	.60542	.60500	.60458	.60416	.60374	.60332
.73	.60290	.60249	.60207	.60165	.60123	.60082	.60040	.59999	.59957	.59915
.74	.59874	.59832	.59791	.59750	.59708	.59667	.59625	.59584	.59543	.59502
.75	.59460	.59419	.59378	.59337	.59296	.59255	.59214	.59173	.59132	.59091
.76	.59050	.59009	.58968	.58927	.58886	.58845	.58805	.58764	.58723	.58682
.77	.58642	.58601	.58561	.58520	.58479	.58439	.58398	.58358	.58317	.58277
.78	.58237	.58196	.58156	.58116	.58075	.58035	.57995	.57955	.57915	.57875
.79	.57834	.57794	.57754	.57714	.57674	.57634	.57594	.57554	.57515	.57475
.80	.57435	.57395	.57355	.57316	.57276	.57236	.57197	.57157	.57117	.57078
.81	.57038	.56999	.56959	.56920	.56880	.56841	.56801	.56762	.56723	.56683
.82	.56644	.56605	.56566	.56527	.56487	.56448	.56409	.56370	.56331	.56292
.83	.56253	.56214	.56175	.56136	.56097	.56058	.56019	.55981	.55942	.55903
.84	.55864	.55826	.55787	.55748	.55710	.55671	.55632	.55594	.55555	.55517
.85	.55478	.55440	.55402	.55363	.55325	.55287	.55248	.55210	.55172	.55133
.86	.55095	.55057	.55019	.54981	.54943	.54905	.54867	.54829	.54791	.54753
.87	.54715	.54677	.54639	.54601	.54563	.54525	.54488	.54450	.54412	.54374
.88	.54337	.54299	.54261	.54224	.54186	.54149	.54111	.54074	.53036	.53999
.89	.53961	.53924	.53887	.53849	.53812	.53775	.53737	.53700	.53663	.53626
.90	.53589	.53552	.53514	.53477	.53440	.53403	.53366	.53329	.53292	.53255
.91	.53218	.53182	.53145	.53108	.53071	.53034	.52998	.52961	.52924	.52888
.92	.52851	.52814	.52778	.52741	.52705	.52668	.52632	.52595	.52559	.52522
.93	.52486	.52449	.52413	.52377	.52340	.52304	.52268	.52232	.52196	.52159
.94	.52123	.52087	.52051	.52015	.51979	.51943	.51907	.51871	.51835	.51799
.95	.51763	.51727	.51692	.51656	.51620	.51584	.51548	.51513	.51477	.51441
.96	.51406	.51370	.51334	.51299	.51263	.51228	.51192	.51157	.51121	.51086
.97	.51051	.51015	.50980	.50945	.50909	.50874	.50839	.50803	.50768	.50733
.98	.50698	.50663	.50628	.50593	.50558	.50523	.50488	.50453	.50418	.50383
.99	.50348	.50313	.50278	.50243	.50208	.50174	.50139	.50104	.50069	.50035
1.0	.50000									

EXPLANATION OF DECAY CALCULATION METHODS

Calculator Method

The radioactivity of an isotope can be calculated as it decays using the following expression:

$A_f = A_i\ e^{-\lambda t}$

where

A_f = final activity at the end of the decay time;

A_i = initial activity measured at some starting time;

t = net decay time in units inverse to λ; and

λ = (lamda) decay constant specific to the radioisotope.

$\lambda = \ln(2) / T_{1/2} = 0.693 / T_{1/2}$

where

$T_{1/2}$ = half life specific to the radioisotope.

So, using a calculator with the $\mathbf{e}^x$ function, decay calculations can easily be performed, as shown in the first section of this appendix.

Decay Factor Method

If you do not have a calculator with the $\mathbf{e}^x$ function, the above expression can be rewritten as follows:

$A_f = X\ A_i$

where

$X = X_n\ (N) \times X_r\ (R)$

N = integer number of half lives in time **t**; and

R = decimal remainder after dividing **t** by $T_{1/2}$. To verify this, remember three important relations regarding exponentials:

$e^{(A + B)} = e^A \times e^B$;

$e^{\ln(A)} = A$; and

$e^{AB} = (e^{A})^{B}$.

Now $\mathbf{t} / T_{1/2} = N + R$

where N is an integer, and R is the remainder less than 1.

For $\mathbf{t}$ = 32.5 hours and $T_{1/2}$ = 6.007 hours,

$\mathbf{t} / T_{1/2} = 32.5 / 6.007 = 5.410$

so that N = 5 and R = 0.410.

Now, to simplify calculations, we can write the above relation as:

$A_f = A_i\, e^{-\lambda t} = A_i\, e^{-\ln(2)\mathbf{t} / T_{1/2}}$

$A_f = A_i\, e^{-\ln(2)(N + R)} = A_i\, e^{-\ln(2)N} \times e^{-\ln(2)R}$

$= A_i \times X_n (N) \times X_r (R)$

$X_n (N) = e^{-\ln(2)N} = (e^{\ln(2)})^{-N} = 2^{-N}$

This expression is used to generate the values in Table 1.

$X_r (R) = e^{-\ln(2)R}$

This expression is used to generate the Decay Factor Chart for values of R from 0.001 to 0.999.

For the above example

$X_n (5) = 0.03125$

$X_r (0.410) = 0.75262$
$A_f = X\, A_i = [X_n (N) \times X_r (R)]\, A_i = [0.03125 \times 0.75262]\, 43$ mCi

$A_f = 1.01$ mCi

APPENDIX E:
PRE-SET CALIBRATION VALUES

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SUPPLEMENTAL ALPHABETICAL LISTING OF ISOTOPES
ATOMLAB 400 and ATOMLAB 500 DOSE CALIBRATORS

Nuclide		Dial Value	Decay Scheme	Average Beta Energy KeV	Half-Life	Expected Uncertainty	
As-76	Arsenic	24.4	Beta -	1068	1.1 days	C	+/- 10%
Au-198	Gold	24.1	Beta -	406	2.69 days	C	+/- 10%
Au-199	Gold	46.7	Beta -	87	3.139 days	C	+/- 10%
Ba-133	Barium	7.4	EC		10.54 years	M	+/- 3%
Bi-213	Bismuth	53.5	Beta -	12.3	45.6 minutes	C	+/- 10%
Br-75	Bromine	8.3	EC, Beta +	499	1.62 hours H(r)=.00056 did not include Se^{75}	C	+/- 10%
Br-76	Bromine	4.4	EC, Beta +	642	16.2 hours	C	+/- 10%
Br-77	Bromine	20.6	EC, Beta+	1.12	2.376 days	C	+/- 10%
C-11	Carbon	10.1	EC, B+	385	20.39 minutes	C	+/- 10%
Cd-109	Cadmium	32.0	EC		1.267 years	C	+/- 10%
Ce/Pr-144	Ce/Praseodymium	57.4	Beta - / Beta -	82 & 1209	285 days/17 minutes	C	+/- 10%
Co-55	Cobalt	5.6	EC, B+	430	17.53 hours Fe^{55} ignored, contribution is insignificant	C	+/- 10%
Co-57	Cobalt	33.7	EC		271.77 days	M	+/- 3%
Co-58	Cobalt	11.5	EC		70.9 days	C	+/- 10%
Co-60	Cobalt	5.0	Beta -	96	5.271 years Cal values defined relative to Co-60		+/- 1%
Cr-51	Chromium	295.0	EC		27.7 days	C	+/- 10%
Cs-134	Cesium	7.1	Beta -	157	2.06 years	C	+/- 10%
Cs-137	Cesium	17.1	Beta -	188	30.0 years		+/- 3%
Cu-61	Copper	12.3	EC ,B+	306	3.408 hours	C	+/- 10%
Cu-62	Copper	9.7	EC ,B+	1280	9.74 minutes	C	+/- 10%
Cu-64	Copper	55.0	Beta +, Beta -	49.8 & 71	12.701 hours	C	+/- 10%
Cu-67	Copper	43.6	Beta -	142	2.58 days	C	+/- 10%
Dy-165	Dysprosium	92.8	Beta -	442	2.334 hours Includes **Bremsstralung contributions	C	+/- 10%
Eu-152	Europium	6.2	EC ,Beta -	496	13.33 years	C	+/- 10%
F-18	Flourine	9.6	EC ,Beta +	242	1.83 hours	S	+/- 3%
Fe-52	Iron	11.9	EC ,Beta +	189	8.275 hours	C	+/- 10%

- Scheme: EC = Electron Capture IT = Isomeric Transition

NOTES

1. Isotope: A/B implies that B is in equilibrium with A
2. Half Life: s = seconds, m = minutes, d = days, y = years
3. Scheme: EC = Electron Capture, B = Beta decay, IT = Isomeric transition, A = Alpha Decay
4. Cal Value = Atomlab Dose Calibrator dial setting to calibrate for corresponding isotope
5. Notes:
   *H(r) = Half-life ratio of daughter over parent, implies daughter is ignored
   **Bremsstrahlung includes implies low energy photons from electron interaction in saline
   Isotope should be measured in plastic syringe or vial or thin wall glass ampule.

Isotope should be measured in plastic syringe or vial or thin wall glass ampule, unless otherwise stated above.

CONFIDENCE VALUES

C	Calculated with corrected Monte Carlo
B	Beta MC, response strongly dependent upon measurement geometry: best if Cal Value used is determined using actual measurement with clinical geometry confidence value of a measurement made using the listed dial value
M	Measured directly
S	Special Case
+/-3%	As stated

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SUPPLEMENTAL ALPHABETICAL LISTING OF ISOTOPES
ATOMLAB 400 and ATOMLAB 500 DOSE CALIBRATORS

Nuclide		Dial Value	Decay Scheme	Average Beta Energy KeV	Half-Life	Expected Uncertainty	
Fe/Mn-52	Iron/Manganese	3.3	EC, Beta + / EC, Beta +	189 & 1133	8.275 hours / 21.1 minutes	C	+/- 10%
Fe-59	Iron	10.5	Beta -	118	44.5 days	C	+/- 10%
Ga-67	Gallium	32.5	EC		3.261 days	S	+/- 3%
Ge/Ga-68	Germanium/ Gallium	10.1	EC/ EC, Beta +	740	270.8 days / 1.14 hours	C	+/- 3%
Gd-153	Gadolinium	8.7	EC		241.6 days	C	+/- 10%
Hg-197	Mercury	24.0	EC		2.67 days	C	+/- 10%
Hg-203	Mercury	32.1	Beta -	58	46.6 days	C	+/- 10%
Ho-166	Holmium	77.0	Beta -	16.5	1.117 days Includes **Bremsstralung contributions	C	+/- 10%
I-122	Iodine	9.5	EC, Beta +	1087	3.62 minutes	C	+/- 10%
I-123	Iodine	12.8	EC		13.2 hours	M	+/- 3%
I-124	Iodine	7.7	EC,Beta +	188	4.18 days	C	+/- 10%
I-125	Iodine	10.8	EC		60.14 days	M	+/- 3%
I-131	Iodine	22.3	Beta -	182	8.04 days	M	+/- 3%
In-111	Indium	13.1	EC		2.807 days	M	+/- 3%
In-113(m)	Indium	31.1	IT		1.6 hours	C	+/- 10%
Ir-192	Iridium	11.1	Beta - & EC	171	73.83 days	C	+/- 10%
Ir-196	Iridium	45.2	Beta -	1170	52 seconds includes **Bremsstahlung contributions	C	+/- 10%
Ir-196	Iridium	4.0	Beta -	337	1.4 hours	C	+/- 10%
K-38	Potassium	3.9	EC, Beta +	1204	7.636 minutes	C	+/- 10%
K-43	Potassium	10.7	Beta -	314	22.3 hours	C	+/- 10%
La-140	Lanthanum	5.4	Beta -	525	1.678 days	C	+/- 10%
Lu-177	Lutetium	114.0	Beta -	133	6.71 days	C	+/- 10%
Mo-99	Molybdenum	175.0	Beta -	390	2.748 days In 1/4 inch lead wall breakthru shield	S	+/- 3%
N-13	Nitrogen	10.1	EC, Beta +	491	9.965 minutes	C	+/- 10%

- Scheme: EC = Electron Capture IT = Isomeric Transition

NOTES

1. **Isotope: A/B implies that B is in equilibrium with A**
2. **Half Life: s = seconds, m = minutes, d = days, y = years**
3. **Scheme: EC = Electron Capture, B = Beta decay, IT = Isomeric transition, A = Alpha Decay**
4. **Cal Value = Atomlab Dose Calibrator dial setting to calibrate for corresponding isotope**
5. **Notes:**
   - ***H(r) = Half-life ratio of daughter over parent, implies daughter is ignored**
   - ****Bremsstrahlung includes implies low energy photons from electron interaction in saline**
   - **Isotope should be measured in plastic syringe or vial or thin wall glass ampule.**

Isotope should be measured in plastic syringe or vial or thin wall glass ampule, unless otherwise stated above.

CONFIDENCE VALUES

C	Calculated with corrected Monte Carlo
B	Beta MC, response strongly dependent upon measurement geometry: best if Cal Value used is determined using actual measurement with clinical geometry confidence value of a measurement made using the listed dial value
M	Measured directly
S	Special Case
+/-3%	As stated

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SUPPLEMENTAL ALPHABETICAL LISTING OF ISOTOPES
ATOMLAB 400 and ATOMLAB 500 DOSE CALIBRATORS

Nuclide		Dial Value	Decay Scheme	Average Beta Energy KeV	Half-Life	Expected Uncertainty	
Na-22	Sodium	5.3	EC, Beta +	195	2.6 years	C	+/- 10%
Nb-95	Niobium	14.7	Beta -	9.8	34.97 days	C	+/- 10%
O-15	Oxygen	10.0	EC, Beta +	735	2.037 minutes	C	+/- 10%
Os-191	Osmium	27.2	Beta -	37.5	15.4 days	C	+/- 10%
P-32	Phosphorus	530.0	Beta - (Pure)	695	14.28 days	B	+/- 20%
Pb-203	Lead	15.0	EC		2.169 days	C	+/- 10%
Pm-149	Promethium	485	Beta -	366	2.212 days includes **Bremsstrahlung ~40%	B	+/- 20%
Pt-195(m)	Platinum	22.6	IT		4.02 days	C	+/- 10%
Pt-197	Platinum	103.0	Beta -	195	18.3 hours	C	+/- 10%
Rb-82	Rubidium	8.7	EC, Beta +	1409	1.273 minutes	C	+/- 10%
Rb/Kr-81	Rubidium/Krypton	14.5	EC, Beta+ / IT	132	4.6 hours / 13 seconds	C	+/- 10%
Re-186	Rhenium	110.3	EC, Beta -	323	3.777 days includes **Bremsstrahlung contributions	C	+/- 10%
Re-188	Rhenium	82.5	Beta -	765	16.98 hours includes **Bremsstrahlung contributions	C	+/- 10%
Sb-124	Antimony	6.6	Beta -	105	60.2 days	C	+/- 10%
Sc-46	Scandium	6.0	Beta -	52	83.83 days	C	+/- 10%
Se-73	Selenium	7.2	EC, Beta +	368	7.15 hours H(r)=.0037, did not include As^{73}	C	+/- 10%
Se-75	Selenium	17.6	EC		119.8 days	C	+/- 10%
Sm-153	Samarium	19.0	Beta -	225	1.946 days in plastic syringe	C	+/- 10%
Sm-156	Samarium	8.1	Beta -		9.4 hours H(r)=.0258, ignored Eu^{156} daughter	C	+/- 10%
Sr-85	Strontium	20.6	EC		64.84 days	C	+/- 10%
Sr-87(m)	Strontium	30.9	IT		2.795 hours	C	+/- 10%

- Scheme: EC = Electron Capture IT = Isomeric Transition

NOTES

1. **Isotope: A/B implies that B is in equilibrium with A**
2. **Half Life: s = seconds, m = minutes, d = days, y = years**
3. **Scheme: EC = Electron Capture, B = Beta decay, IT = Isomeric transition, A = Alpha Decay**
4. **Cal Value = Atomlab Dose Calibrator dial setting to calibrate for corresponding isotope**
5. **Notes:**
   - ***H(r) = Half-life ratio of daughter over parent, implies daughter is ignored**
   - ****Bremsstrahlung includes implies low energy photons from electron interaction in saline**
   - **Isotope should be measured in plastic syringe or vial or thin wall glass ampule.**

Isotope should be measured in plastic syringe or vial or thin wall glass ampule, unless otherwise stated above.

CONFIDENCE VALUES

C	Calculated with corrected Monte Carlo
B	Beta MC, response strongly dependent upon measurement geometry: best if Cal Value used is determined using actual measurement with clinical geometry confidence value of a measurement made using the listed dial value
M	Measured directly
S	Special Case
+/-3%	As stated

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SUPPLEMENTAL ALPHABETICAL LISTING OF ISOTOPES
ATOMLAB 400 and ATOMLAB 500 DOSE CALIBRATORS

Nuclide		Dial Value	Decay Scheme	Average Beta Energy KeV	Half-Life	Expected Uncertainty	
Sr-89	Strontium (Pure Sr-89, NIST Grade *Brems)	**686.0**	Beta -	583	50.55 days Pure Sr-89, NIST Grade, Brems	B	+/- 20%
Sr-89(m)	Strontium	**X**	Beta -	583	50.55 days Metastron, Brems… with Sr-85 impurity		+/- 20%
Ta-178	Tantalum	**16.6**	EC		9.31 minutes Pure	C	+/- 10%
Tc-99m	Technetium	**37.1**	IT		6.007 hours		+/- 3%
Tl-201	Thalium	**20.9**	EC		3.046 days		+/- 3%
W-178	Tungsten	**68.7**	EC		21.5 days Pure	C	+/- 10%
W-178/ Ta-178 Equilibrium	Tungsten/ Tantalum	**13.4**	EC / EC		21.5 days / 9.31 minutes Ta-178 in equilibrium with W-178 (use for W Contamination activity)	C	+/- 10%
W/ReEq-188	Tungsten	**82.1**	Beta -	99 & 765	69.4 days includes **Bremsstrahlung contributions from Re^{188}	C	+/- 10%
Xe-127	Xenon	**11.0**	EC		36.4 days	C	+/- 10%
Xe-133	Xenon	**19.5**	Beta -	100	5.245 days	M	+/- 3%
Y-86	Yttrium	**3.4**	Beta +	2.88	14.74 hours B+ contribution is ~12%	C	+/- 10%
Y-88	Yttrium	**4.9**	EC		106.6 days	C	+/- 10%
Y-90	Yttrium	**350.0**	Beta -	934	2.671 days **Bremsstrahlung only, 10cc plastic syringe (from 2002 vol study)	S	+ / 5%
Y-90	Yttrium	**375.0**	Beta -	934	2.671 days **Bremsstrahlung only, NIST vial measurement	S	+ / 3%
Yb-169	Ytterbium	**5.5**	EC		32 days	C	+/- 10%
Zn-65	Zinc	**21.2**	EC, Beta +	2	244.1 days B+ contribution is ~3%	C	+/- 10%

- Scheme: EC = Electron Capture IT = Isomeric Transition

NOTES

1. **Isotope: A/B implies that B is in equilibrium with A**
2. **Half Life: s = seconds, m = minutes, d = days, y = years**
3. **Scheme: EC = Electron Capture, B = Beta decay, IT = Isomeric transition, A = Alpha Decay**
4. **Cal Value = Atomlab Dose Calibrator dial setting to calibrate for corresponding isotope**
5. **Notes:**
   - ***H(r) = Half-life ratio of daughter over parent, implies daughter is ignored**
   - ****Bremsstrahlung includes implies low energy photons from electron interaction in saline**
   - **Isotope should be measured in plastic syringe or vial or thin wall glass ampule.**

Isotope should be measured in plastic syringe or vial or thin wall glass ampule, unless otherwise stated above.

CONFIDENCE VALUES

C	Calculated with corrected Monte Carlo
B	Beta MC, response strongly dependent upon measurement geometry: best if Cal Value used is determined using actual measurement with clinical geometry confidence value of a measurement made using the listed dial value
M	Measured directly
S	Special Case
+/-3%	As stated

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SUPPLEMENTAL ALPHABETICAL LISTING OF ISOTOPES
ATOMLAB 400 and ATOMLAB 500 DOSE CALIBRATORS

Nuclide		Dial Value	Decay Scheme	Average Beta Energy KeV	Half-Life	Expected Uncertainty	
Zr/Y(m)-89	Zircon/Yttrium	**10.0**	EC, Beta + / IT	7.1	3.268 days / 16.1 seconds	C	+/- 10%

Dial Value Settings and Source Containers (Glass Vial, Glass Syringe, etc.)
The Atomlab Dial Value (DV) settings enable the software to convert ion chamber current into a displayed activity value for the isotope corresponding to the DV selected. The displayed activity value is directly proportional to the DV.

The isotope's "*source container*" is either a vial or syringe; the composition of the vial or syringe MAY influence the accuracy of the activity measurement. The DV supplied in the Atomlab User Guide (Instruction Manual), or pre-programmed into the isotope dial value, *are calibrated for use with the source material in an un-shielded plastic syringe (nominal 1mm wall)*, while hanging in the supplied "source dipper" syringe support. For isotopes contained in sealed long lived QA sources (Cs-137, etc.), the DV supplied are calibrated for use with type Vial E epoxy sources or equivalent. Yttrium-90 is listed in both a plastic syringe and a vial.

Accurate measurement of unsealed sources in any other configuration must be with a new Container Dial Value *"CDV", determined by the USER* with the following procedure. During following steps, set DV to the Atomlab published value.

Container with NO source material

1 Assay a quantity of isotope source material in a plastic syringe, nominal wall thickness of 1mm, record as *(Plastic Syringe Activity)1*.
2 Transfer part or all of the source material from the plastic syringe into the empty Container.
3 Assay the Container with the isotope source material, record as *(Container Activity)*.
4 Assay the partial or "empty" plastic syringe for residual activity, record as *(Plastic Syringe Activity)2*.
5 Calculate the Container Dial Value for use with isotope assayed in that type of container,
*CDV = DV * (PSA1 - PSA2) / (Container Activity)*
where *PSA = Plastic Syringe Activity*

Container with source material

1 Assay Container with the isotope source material, record as *(Container Activity) 1*.
2 Transfer part or all of the source material from the Container into a plastic syringe, nominal wall thickness of 1mm.
3 Assay the plastic syringe with the isotope source material, record as *(Plastic Syringe Activity)*.
4 Assay the partial or "empty" Container for residual activity, record as *(Container Activity)* 2.
5 Calculate the Container Dial Value for use with isotope assayed,
*CDV = DV * PSA / (CA1-CA2)*
where *PSA* = Plastic Syringe Activity and *CA* = Container Activity.
Typically, for glass wall source Containers, CDV will be higher than DV when the isotope has a significant portion of low energy photons in its emission spectrum.

- Scheme: EC = Electron Capture IT = Isomeric Transition

NOTES

1. **Isotope: A/B implies that B is in equilibrium with A**
2. **Half Life: s = seconds, m = minutes, d = days, y = years**
3. **Scheme: EC = Electron Capture, B = Beta decay, IT = Isomeric transition, A = Alpha Decay**
4. **Cal Value = Atomlab Dose Calibrator dial setting to calibrate for corresponding isotope**
5. **Notes:**
   ***H(r) = Half-life ratio of daughter over parent, implies daughter is ignored**
   ****Bremsstrahlung includes implies low energy photons from electron interaction in saline**
   Isotope should be measured in plastic syringe or vial or thin wall glass ampule.

Isotope should be measured in plastic syringe or vial or thin wall glass ampule, unless otherwise stated above.

CONFIDENCE VALUES

C	Calculated with corrected Monte Carlo
B	Beta MC, response strongly dependent upon measurement geometry: best if Cal Value used is determined using actual measurement with clinical geometry confidence value of a measurement made using the listed dial value
M	Measured directly
S	Special Case
+/-3%	As stated

DIAL SETTINGS FOR Y-90

The typical Atomlab 400 Dose Calibrator dial setting for Y-90 activity in a 10 cc plastic syringe is 350. This value can be used as a starting point for initial measurements. However, it is recommended that the dial setting used for clinical measurements be determined from the first dose of Zevalin received from the radiopharmacy, as outlined below. Following doses should then be compared to the radiopharmacy doses for constancy.

The Y-90 recipient, using an Atomlab dose Calibrator, should determine the correct dial value from the first Y-90 dose that they receive from a commercial radiopharmacy. This is determined by selecting the Y-90 button and adjusting the dial setting until the displayed activity agrees with the decay corrected Y-90 syringe activity as stated by the commercial radiopharmacy. If the adjusted dial setting falls within the range of 333 to 368, then use that dial setting.

If it falls outside the range, verify that:
- there is a well liner in place
- a hook style dipper is used
- the annual accuracy and daily constancy test results are acceptable

If these criteria are met, then determine the percent difference of the new dial value with respect to the nearest range limit value (333 or 368), i.e. Dial Value Error (DVE). Add this percent to the Change in Constancy Percent Error (CCPE). If the sum of the errors is in the range of -2% to +2%, then the new dial value should be used. If not, contact Biodex Technical Support. The user may also want to contact the radiopharmacy to determine if a calibration error may have occurred.

NOTE: *The CCPE is the percent change from calibrator installation of the constancy measurement, where CCPE = "Today's" Constancy Percent Error – "Installation's" Constancy Percent Error. The Constancy Percent Error is the measurement error with respect to the decay corrected source activity. A change down in the Atomlab Calibrator constancy will cause a change up in the dial value required to compensate the change in constancy, and visa-a versa. Thus, the CCPE will have the opposite sign as the DVE, so adding them should cancel to within 2%.*

For example, a new dial value for Y-90 is found to be 374. This falls outside the range and is +1.5% higher than 368. The constancy measurement shows a -2.5% change since the Dose Calibrator was installed. Their sum is (+1.5%) + (-2.5%) = -1.0%, which within -2% and +2%. The dial value of 374 should be used.

NOTE: *For all Dose Calibrator Models, the well liner must be installed before making measurements. The well liner provides attenuation for the Y-90 betas that would otherwise enter the chamber and cause high readings.*

NOTE: *The dial value range provided above is for use with plastic syringes; due to the wide variation in styles between vials it is recommended that the user determine the dial value for vials themselves. This can be done using a vial containing a known activity of Y-90, by changing the dial value until the activity read using the Y-90 button matches the known activity within the vial.*

APPENDIX F:
ATOMLAB DOSE CALIBRATOR
CALIBRATION AND TRACEABILITY

This appendix describes the calibration procedures performed on your Atomlab Dose Calibrator and their traceability to the National Institute of Standards & Technology.

CALIBRATION & TRACEABILITY

The calibration of the Atomlab Dose Calibrators is directly traceable to the National Institute of Standards & Technology, formerly the National Bureau of Standards (NBS). This is achieved through the establishment of a set of working laboratory standards, the maintenance of these working standards, and the use of these working standards to calibrate each Atomlab Dose Calibrator.

The working standards consist of two ionization chambers identical to the chambers used in each Atomlab Dose Calibrator for radiation measurement, and several long-lived radiation sources.

The two standard ionization chambers have been calibrated using radionuclides that were calibrated by the National Institute of Standards & Technology, generating response numbers. These response numbers were then used to determine the photon response function of the ionization chambers. The shielding configuration is identical to that of the Atomlab Dose Calibrator design.

The National Institute of Standards & Technology sources are in glass ampule form and, because of the potential for breakage, are not suitable for routine calibration. Instead the working standards are in epoxy resin form in a plastic vial E package. These standards have been calibrated against the National Institute of Standards & Technology sources in the two standard ionization chambers. Together, the chambers and the sources provide a high degree of accuracy and redundancy. Periodically, the source activity is measured in the two standard chambers and the results are compared to the expected decayed activity.

The Atomlab Dose Calibrator must first pass all electronic testing and operate for three days prior to calibration. Calibration then takes place with the Co-60 working standard. The calibration value is stored in a special memory chip on the chamber circuit board. Calibration is then verified by measuring the activity of all the working standards, including Co-60, Cs-137, Ba-133, and Co-57.

Finally, a Tc-99m source in a 10 ml vial of saline is calibrated in the two standard ionization chambers. After calibration, the response to the Tc-99m standard is measured and verified to be within 2%.

APPENDIX G:
ATOMLAB 400 SERIAL COMMUNICATIONS INTERFACE

The Atomlab 400 has the ability to be controlled and monitored, with limitations, via the DB-9 RS-232 serial port.

CONNECTION DETAILS

Cable: RS-232 Male/Female wired straight through, for connection to a standard PC COM Port
Port Settings: 19.2 KBAUD, no parity, 1 stop

COMMAND FORMAT

All commands are in ASCII format, terminated by a Carriage Return (0x0D), and no longer than 7 letters. If a parameter is given, the command must be separated from the parameter by at least 1 space and/or comma. If the command or parameter has a format error, or a numeric parameter is out of range, an error message is sent out the serial port, terminated by a CR/LF. All data transmitted as a result of a command is also in ASCII and terminated by a CR/LF.

USAGE NOTES

Some of these commands that actively change settings and operation of the display can cause corruption of an activity someone may be in progress of at the display console. These remote commands must be used with great care and consideration of how the unit is being used.

COMMAND DESCRIPTIONS

There are commands to report status, and some control the unit. Following is a list with descriptions in alphabetic order.

^C (Hex: 0x03) Sends the most current activity reading out the serial port. A Carriage Return (0x0D) is not required. Please refer to the DS command for details of the activity report format.

1 (Hex: 0x31) same as ^C above. A Carriage Return (0x0D) is not required.

? Displays all available commands with a brief description.

BEEP ### Issues a beep tone on the display for “###” milliseconds. If not specified, it defaults to 100. Longest beep sounded can be for 10 seconds.

BCKGND This command will do a Zero Background on the connected chamber. If the command cannot be performed, the following error will be returned:

ERROR: Measure Screen Not Active
{the Measure screen must be on view for this command to work}

If the command succeeds, it may be done instantly, taking effect on the very next activity reading, or may take up to 100 readings. If the Zero Background does not happen instantly, each reading from that detector will be preceded by:
~ Calculating background… {followed by CR/LF}

When this command is received, the Zero Background screen will be displayed. However if any screen other than the Measure screen is on view, a Zero Background cannot be performed, and the displayed screen will not be affected.

DS {1/0} Turns Data Streaming Mode On=1, Off=0. If no parameter is given, the current Data Streaming Mode is displayed. When On, every time a reading is reported from a chamber, the isotope's symbol, dial values, and activity reading is reported continuously until turned off. If there is more than 1 chamber connected, the detector number is appended on the end of each report. The report starts with a tilda (~) character with the fields separated by a space. The activity reading always has 3 decimal digits in the report followed by the units. Here is an example of a report: ~Tc-99m 37.1 1404.767 uCi

DSTAT Displays Detector Status. The data returned is in this order separated by a space: Detector Id, High Voltage, Pressure, Temperature, and Argon gas in grams. Here is an example of the returned data: 10 353.9 245.0 23.4 6.9

ECHO {1/0} Display or turn local character echo ON (=1) or OFF (=0). Local character echo is ON by default. If using data streaming, this should be turned OFF to avoid mangling the streaming reports.

FIRM {1/2} Displays which one of the 2 main firmware programs is active and scheduled. It can also select the other main firmware program to be scheduled to run upon the next reset.

HELP Same as the "?" command, displays all available commands with a brief description.

ISO {#} Displays or sets the Isotope for activity measurement. The parameter is an isotope index number, 1 to 88 for the default isotopes, 89 and 90 for custom isotopes. Refer to the separate Isotope Index List at the end of Appendix G for details. If no parameter is given, the current assigned isotope is displayed. Use this command with great care.

Example of a command:
ISO 43 {sets isotope Tc-99m for detector #2}

The Following errors may be returned:
ERROR: Invalid Isotope Index #
{a number greater than 90 was specified}
ERROR: Measure Screen Not Active
{the Measure screen must be on view for this command to work}

When this command is received, the newly selected isotope will be displayed, and the activity changed accordingly. However if any screen other than the Measure screen is on view, the isotope cannot be changed, and the displayed screen will not be affected.

MEAS Displays the Main Messure screen unconditionally

RESET Immediately reset and reboots the Atomlab display. It will be at least 110 seconds before activity readings can be taken in the chambers.

SETID #-# Changes a detector Id specified as “from-to”. Valid Id’s are: 2, 4, 6, 8, 10, 12, and 14.

SSAV # Sets the screen saver time in seconds. It’s in effect only until the next reboot, then the configured screen saver takes effect. If no parameter is given, it displays the current screen saver time in effect.

STAT {1/0} This is for more advanced chamber status viewing. This command will turn on an on-screen display of chamber status on the Count screen (1=Set On, 0=Turn Off). If no parameter is given, a detailed state of the current connected chamber is displayed.

VER Displays the Atomlab display unit’s firmware versions. Two lines are displayed. The first line shows the version and date of the current running main firmware program. The second line displays what firmware is loaded as Main #1, Main #2, and the boot firmware. Here is an example:
0.84 07/06/2007 (Running)
0.84/0.82/1.03 (MAIN#1/MAIN#2/BOOT)

ATOMLAB 400 ISOTOPE INDEX

Index	Symbol
1	C-11
2	N-13
3	O-15
4	F-18
5	Na-22
6	P-32
7	K-38
8	K-43
9	Sc-46
10	Cr-51
11	Fe-52
12	Fe/Mn-52
13	Co-55
14	Co-57
15	Co-58
16	Fe-59
17	Co-60
18	Cu-61
19	Cu-62
20	Cu-64
21	Zn-65
22	Cu-67
23	Ga-67
24	Ge/Ga-68
25	Se-73
26	Br-75
27	Se-75
28	As-76
29	Br-76
30	Br-77
31	Rb/Kr-81
32	Rb-82
33	Sr-85
34	Y-86
35	Sr-87m
36	Y-88
37	Sr-89m
38	Sr-89
39	Zr/Y-89m
40	Y-90s
41	Nb-95
42	Mo-99
43	Tc-99m
44	Cd-109
45	In-111
46	In-113m
47	I-122
48	I-123
49	I-124
50	Sb-124
51	I-125
52	Xe-127
53	I-131
54	Ba-133
55	Xe-133
56	Cs-134
57	Cs-137
58	La-140
59	Ce/Pr-144
60	Pm-149
61	Eu-152
62	Gd-153
63	Sm-153
64	Sm-156
65	Dy-165
66	Ho-166
67	Yb-169
68	Lu-177
69	Ta-178
70	W-178
71	W/Ta-178
72	Re-186
73	Re-188
74	W/Re-188
75	Os-191
76	Ir-192
77	Pt-195m
78	Ir-196
79	Ir-196p
80	Hg-197
81	Pt-197
82	Au-198
83	Au-199
84	Tl-201
85	Hg-203
86	Pb-203
87	Bi-213
88	Y-90v
89	New Iso 1 or 1st Custom
90	New Iso 2 or 2nd Custom

03/11/2009

APPENDIX H:
ELECTROMAGNETIC COMPATIBILITY

NOTE: *This MEDICAL ELECTRICAL EQUIPMENT needs special precautions regarding EMC and needs to be installed and put into service according to the EMC information provided in the ACCOMPANYING DOCUMENTS.*
See chart on next page.

NOTE: *Portable and mobile RF communications equipment can affect MEDICAL ELECTRICAL EQUIPMENT.*

NOTE: *Contact Biodex Medical Systems for additional EMC information.*

ELECTROMAGNETIC COMPATIBILITY FOR ATOMLAB DOSE CALIBRATORS

Standard	Test Method	Range			Limits	Result
IEC 61000-3-2	Harmonics	100 Hz to 2KHz			Class A	THD = 226.76%
IEC 61000-3-3	Flicker	observation time (TP) 10 min			-	-
		max voltage change (dmax)			4%	.0%
		max Rel steady state voltage change (dc)			3%	.00%
		duration of d(t)>3%(t)			.2 sec	0.00 sec
		short term flicker Sev (PST)			1.00	.0
		long term flicker Sev (PLT)			.65	.0
IEC 61000-4-2	Electrostatic Discharge	2Kv / 4Kv / 6Kv pos/neg 1pps for 10sec			no degradation of performance	complied *
IEC 61000-4-3	Radiated Immunity	80MHz to 2500 MHz/3v/m/Horiz & Vertical 1Khz AM, 80% Sine Wave			no degradation of performance	complied
IEC 61000-4-4	Electrical Fast Transient/Burst, Power Leads	PWR Input leads 500v, 1Kv, 2Kv / pos & neg/5KHz REP Rate			no degradation of performance	complied
IEC 61000-4-6	Conducted Immunity, Power Leads	150 KHz to 80 MHz /3Vrms 1Khz, 80% AM			no degradation of performance	complied
IEC 61000-4-8	Magnetic Immunity	3A/M RMS @ 50/60 Hz			no degradation of performance	complied
IEC 61000-4-11	Voltage Dips and Interrupts	**Int Duration**	**Pause between**	**% reduction**	no degradation of performance	complied
		Int 20msec	pause 10 sec	>95%	no degradation of performance	complied
		Int 100msec	pause 10 sec	60%	no degradation of performance	complied
		Int 500msec	pause 10 sec	30%	no degradation of performance	complied
		Int 5000msec	pause 10 sec	>95%	no degradation of performance	complied
CISPR 11	Conducted Emissions	150 KHZ-30 MHz, Class B, Group 1			66/56 dbuV QP 56/46 dbuV AV	complied
CISPR 11	Radiated Emissions	30 MHz – 1GHz, Class B, Group 1			30/37 dbuVm @ 10 m	complied
IEC 61000-4-5	Surge Immunity, Power Leads	500v, 1 Kv, differential, 2 Kv Commons Pos, Neg 1ppm			no degradation of performance	complied

* Reference test results for details

Date: 3/14/08

Atomlab 400\Rick Prince - dc methods test.doc :cs:dv

APPENDIX I: DETERMINING DIAL VALUES

Because the dose calibrator is not inherently capable of detecting which radioisotope has been inserted in the re-entrant chamber, the user must select which isotope is currently being measured. Each radioisotope selection has a corresponding calibration value (also referred to as a "dial value" for historical reasons.) The dial value for a given isotope is a unitless number which is a means of expressing the chamber's sensitivity to the radiation produced by that isotope. Dial values are defined relative to Co-60, an isotope chosen for its high energy gamma radiation and long term stability. The chamber response R for a given isotope is defined as the amount of chamber current produced by a given amount of isotope activity:

$$R_{isotope} = \frac{chamber\ current}{isotope\ activity} \qquad (1)$$

The dial value for Co-60 is defined to be 5.0. The dial value for any other isotope is defined as 5.0 times the response of the chamber to Co-60 divided by the response of the chamber to the isotope:

$$Dial\ value_{isotope} = 5.0 \times \frac{R_{Co-60}}{R_{isotope}} \qquad (2)$$

The response of the chamber can be calculated as the sum of the chamber sensitivity to photons of energy e, times the intensity of the photon radiation of energy e from the radioisotope:

$$R_{isotope} = \sum S_e I_e \qquad (3)$$

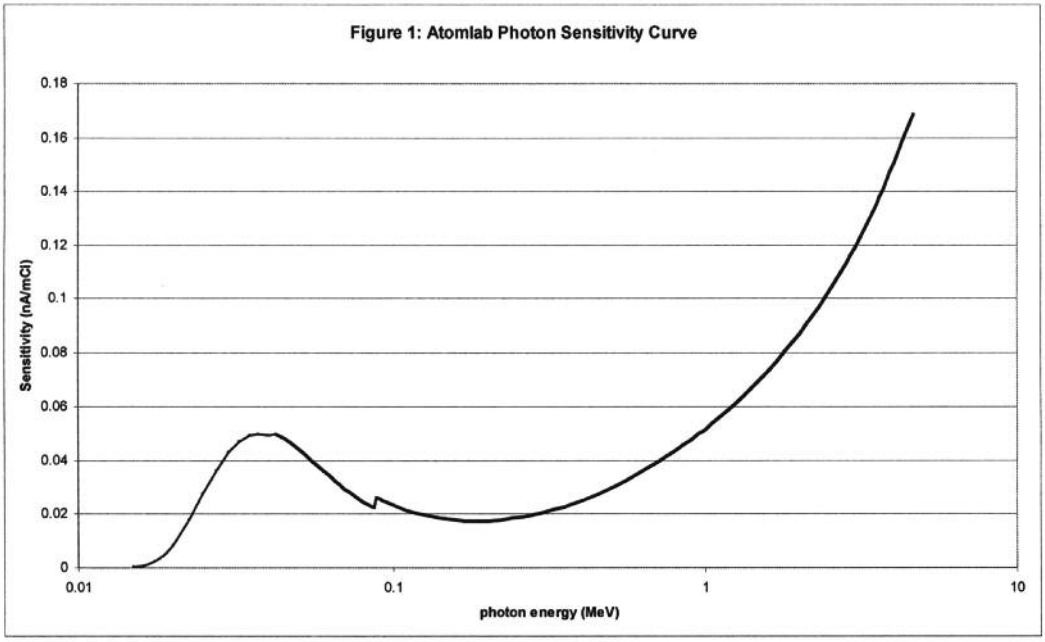
Where the sensitivity of the detector chamber to photons of energy e, in nA/mCi is:

$$S_e = \frac{chamber\ current\ (nA)}{3.7 \times 10^7\ photons\ of\ energy\ e} \qquad (4)$$

A sensitivity curve can be made by plotting the sensitivity of a detector with respect to photon energy. Given the photon sensitivity curve and the intensity of photon emission from radioisotopes (which are tabulated in sources such as reference 1 and 2), the chamber response and dial value can be calculated using equations (1), (2) and (3). The calculated dial values for many common isotopes are listed in the appendix to this manual.

The sensitivity curve of the Atomlab chamber with respect to photon energy has been determined by means of measuring NIST calibrated isotopes at a multitude of photon energies. The isotopes Ga-67, Tc-99m, Mo-99, In-111, I-125, I-131, Xe-133, and Tl-201 were provided from the NIST Standard Reference Materials program. In addition, NIST traceable sources of the isotopes F-18, Co-57, Co-60, Ba-133, and Cs-137 were measured. All of the NIST SRM isotopes with the exception of Xe-133 were contained liquid solutions of 5 ml volume, in sealed borosilicate glass ampules of wall thickness 0.6 mm. The Xe-133 samples were sealed, mixed with non-radioactive xenon gas, in borosilicate glass ampules of wall thickness 1.3 mm. The F-18 source was measured in a 10 ml B-D plastic syringe. The Co-57, Co-60, Ba-133, and Cs-137 sources were contained within epoxy sealed Type E vials.

In addition to the isotopes measured, a Monte Carlo simulation of the Atomlab chamber has been created. The Monte Carlo simulation allows better determination of the shape of the sensitivity curve in the regions between measured data points. The photon sensitivity curve generated by the Monte Carlo simulation was found to be consistent with the sensitivity curve generated by the isotope measurements. The Atomlab chamber sensitivity curve is plotted below, with a logarithmic scale for photon energy:



The accuracy for dial value calculation depends upon not only the accuracy of the sensitivity curve and the photon emission intensity data, but also upon the sample configuration, due to low energy photon absorption (see Radioisotope container below). The photon sensitivity curve displayed is for sources with configurations similar to the NIST ampoule configuration noted above.
All Atomlab dose calibrators are calibrated with NIST traceable Co-60, Ba-133, Co-57, and Cs-137 sources. Each dose calibrator is certified to measure the correct activity of the calibration sources to within the specified accuracy.

The following factors can affect measurement accuracy and should be taken into consideration when using the Atomlab dose calibrator:

Lead Shield: A lead shield is necessary to protect personnel from exposure to the radiation produced by radioactive isotopes. This lead shield is integrally installed as part of the Atomlab dose calibrator. However, photon backscatter occurs from the lead shield, resulting in increased chamber sensitivity in the 88-200 keV photon energy range. This increase in sensitivity is already included in the sensitivity curve above, and it can be easily seen in the peak at 88 keV. However, if for any reason the dose calibrator is operated without the integral shield installed, the sensitivity curve will be incorrect in this energy range, resulting in incorrect measurements for isotopes which emit photons in this range. It is recommended that the dose calibrator always be operated with the lead shield in place.

Radioisotope container: The style and type of container a radioisotope is in can effect the measurement. Users should have a standard procedure, container, and solution volume for measuring radioisotopes. Plastic syringes are often used as a standard container as they are usually the means of delivery to the patient in a clinical environment. The dial values generated using the photon sensitivity curve above should be appropriate for most plastic and thin glass syringes. Glass vials may require a correction factor for some isotopes.

The wall thickness of the container is especially important when measuring isotopes which emit low energy photon and/or high energy beta radiation. I-125, I-123, and Xe-133 are especially susceptible to errors caused by low energy photon absorption. In cases where a container has a wall thickness or material significantly different from the NIST standards used above, it is recommended that a correction factor or corrected dial value be used to correct for the difference in absorption between the NIST configuration and the configuration used in clinical practice. Whichever container and configuration is used in clinical practice, it is strongly recommended that such configuration be standardized and used every single time.

Determining Your Own Dial Values

Dial Values can be determined by the user for isotopes for which no published dial value exists. In order to do this, you will need a sample for which the activity value is known. The activity value may be provided by the isotope producer or pharmacy, or it may be measured by a method independent of the dose calibrator. The accuracy of the dial value will depend upon the accuracy of the known activity value of the sample used; because of this, it is best if an estimate of the accuracy of the isotope calibration is available.

To determine the dial value for the isotope, select the Co-60 isotope key and measure the isotope sample in the same container and geometry which will be used to measure the isotope in clinical practice. The dial value can then be calculated by the following formula:

$$\textit{New Dial value} = 5.0 \times \frac{\textit{activity}}{\textit{measurement}}$$

where the activity is the known activity of the source and the measurement is the displayed activity when measured on the Co-60 isotope key. Remember to decay correct the source's activity for time elapsed since source activity calibration.

Once the new dial value has been calculated, a new isotope name should be created on the display for the isotope, with the dial value as calculated above. Then, the source should be measured again and compared with its known time-decayed activity, in order to verify that the calculation is correct. It may be necessary to adjust the dial value very slightly in order to match the known activity – if necessary, do so at this time.

Once the dial value has been determined by means of comparison to a source of known activity, it should not be changed unless access to a source with an activity known to higher accuracy allows determination of a more accurate dial value. Dial values should never be adjusted daily to make a source match daily isotope measurements. The dial value should only be determined with a calibrated isotope source of known accuracy.

Biodex supplies dial values for many isotopes. Many of these dial values are calculated using a Monte Carlo simulation corrected by actual measurements. If a source is available which has calibrated accuracy better than the uncertainty listed in the table in Appendix E, then this source can be used to modify the dial value for an existing isotope.

Biodex is interested in users' measurements which have better accuracy than the uncertainty listed in the dial value table. If you have a more accurate dial value for an isotope listed in the table, please contact us and supply documentation including the measurements, isotope calibration (and independent measurement method), measurement geometry and source container, and calculation, so that we may share this information with other users.

References:

1) National Nuclear Data Center, *Nudat 2.2 Database,* Upton, NY: Brookhaven National Laboratory, 2007

2) Browne, Edgardo, and Richard B. Firestone, *Table of Radioactive Isotopes,* New York: John Wiley and Sons, Inc., 1986

3) David C. Rayburn, *Determination of the Response Characteristics of the Atomlab Re-entrant Ionization Chamber,* Melbourne, FL: Florida Institute of Technology, 2007

APPENDIX J: QUALITY ASSURANCE TESTING OF ATOMLAB® DOSE CALIBRATORS (MANUFACTURER'S* INSTRUCTIONS)

Introduction

The following procedures are the manufacturer's instructions for qualifying AtomLab® 100, 100+, 200, 300, 400, and 500 dose calibrators in accordance with NRC regulation 10 CFR 35.60 of 1 January 2003 (or applicable agreement State Regulation). Use of these instructions outside the USA may require modification in order to satisfy local regulations.

Qualification is the determination of errors associated with the following tests at the indicated frequency. Acceptable errors for each test are indicated in parentheses.

- **Constancy:** Starting at installation and at least once each day before measuring patient dosages (±5 percent).
- **Dial Value Setting:** at first receipt of isotope activity in container other than a plastic syringe (±10% from decay corrected calibration activity).
- **Linearity:** at installation and at least quarterly thereafter (±5 percent).
- **Geometry:** at installation (±5 percent).
- **Accuracy:** at installation and at least annually thereafter (±5 percent).

After repair of the dose calibrator, repeat the above tests as a new installation.

NOTE: A plastic well liner and source dipper must be used in all measurements.

NOTE: If possible, leave the dose calibrator powered-on 24 hours a day, 7 days a week. If not, allow 1 hour warm-up after power-on before performing these procedures.

NOTE: We have an acceptance variance percentage listed for each test. These are the default settings. You can use ±10% for acceptability and ±5% for investigation. Call Biodex Service Dept. if readings are outside the acceptable range. The default acceptable range is based on 10CFR35.60 of January 1, 2003 and IEC-61145. You must consider what your state or government regulations require.

NOTE: Assay means to place the source container into the dose calibrator so that the dipper is resting in the well liner.

NOTE: The AtomLab® 500 control module has built-in Constancy, Linearity, Geometry, and Accuracy software functions which provide ease-of-use to the user in performing the functions below.

Constancy

Constancy means reproducibility in measuring the same source, over a period of time, with decay correction.

Assay a relatively long-lived source (such as Cs-137) each day before using the calibrator.

Cs-137, 100 μCi minimum activity, is strongly recommended because the 30-year half life will assure use of the same source throughout the life of the calibrator, and it is readily available.

Consider using the following procedure or equivalent:

1. Press the Zero Background (Bkgnd) button. When the display zeroes, the unit has automatically adjusted for Background.
2. Assay each reference source using the appropriate dose calibrator setting (i.e., use the Cs-137 setting to assay Cs-137.)
3. Record the activity reading of the constancy source in a permanent log.
4. Compare the measurement observed to the calculated activity of the source and if the measurement exceeds 5% of predicted, investigate potential sources of error (patients in the area, exposed sources, use of the wrong isotope or setting, etc.)
5. If the constancy result is determined to be greater than 10% of predicted, suspend the use of the instrument and repair or replace the dose calibrator.

NOTE: It is recommended that the Cs-137 and Ba-133 sources be replaced when the activity is below 100 μCi. It is recommended to replace a Co-57 source when the activity is less than 1 mCi.

**Manufactured by Sun Nuclear Corporation, Melbourne, FL; distributed by Biodex Medical Systems.*

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Dial Value Settings and Source Containers (Glass Vial, Glass Syringe, etc.)

The Atomlab Dial Value (DV) settings enable the software to convert ion chamber current into a displayed activity value for the isotope corresponding to the DV selected. The displayed activity value is directly proportional to the DV.

The isotope's "*source container*" is either a vial or syringe; the composition of the vial or syringe MAY influence the accuracy of the activity measurement. The DV supplied in the Atomlab User Guide (Instruction Manual), or pre-programmed into the isotope buttons, *are calibrated for use with the source material in an un-shielded plastic syringe (nominal 1mm wall)*, while hanging in the supplied "source dipper" syringe support. For isotopes contained in sealed long lived QA sources (Cs-137, etc.), the DV supplied are calibrated for use with type Vial E epoxy sources or equivalent.

Accurate measurement of unsealed sources in any other configuration must be with a new Container Dial Value "*CDV*", *determined by the USER* with the following procedure.

NOTE: This is important to determine the appropriate Dial Value for Beta and low energy gammas when the container (syringe or vial) changes.

During following steps, set DV to the Atomlab published value.

Container with no source material

1. Assay a quantity of isotope source material in a plastic syringe, nominal wall thickness of 1mm, record as $(Plastic\ Syringe\ Activity)_1$.
2. Transfer part or all of the source material from the plastic syringe into the empty Container.
3. Assay the Container with the isotope source material, record as *(Container Activity)*.
4. Assay the partial or "empty" plastic syringe for residual activity, record as $(Plastic\ Syringe\ Activity)_2$.
5. Calculate the Container Dial Value for use with isotope assayed in that type of container,

$$CDV = DV \cdot \frac{(PSA)_1 - (PSA)_2}{(Container\ Activity)}$$

where PSA = *Plastic Syringe Activity*.

Container with source material

1. Assay Container with the isotope source material, record as $(Container\ Activity)_1$.
2. Transfer part or all of the source material from the Container into a plastic syringe, nominal wall thickness of 1mm.
3. Assay the plastic syringe with the isotope source material, record as *(Plastic Syringe Activity)*.
4. Assay the partial or "empty" Container for residual activity, record as $(Container\ Activity)_2$.
5. Calculate the Container Dial Value for use with isotope assayed,

$$CDV = DV \cdot \frac{(PSA)}{(CA)_1 - (CA)_2}$$

where PSA = Plastic Syringe Activity and CA = Container Activity.

Typically, for glass wall source Containers, CDV will be higher than DV when the isotope has a significant portion of low energy photons in its emission spectrum.

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Linearity

Linearity means the proportionality of the measurement result to the activity measured, as determined over the intended range of use for the dose calibrator.

This test is done using a vial or syringe of Tc-99m whose activity is at least as large as the maximum activity normally assayed in a prepared radio pharmaceutical kit, in a unit dosage syringe, or in a radio pharmaceutical therapy, whichever is largest.

There are several acceptable methods for preparing linearity testing. The difference in these methods is which reading is used for decay correction of the activities. The following methods are all acceptable for determining the normalized value.

a. Decay correct the test sample from the first reading and compare each reading to the decay corrected reading.

b. For Tc-99 select 30 hours as the normalized reading, and decay correct this reading to calculate the expected activities at the times you took your readings. Compare the readings to the calculated activities. You can change from 30 hours to another time point and perform your normalized calculation from that time point.

   The Atomlab 500 automated linearity test uses 30 hours as the default method.

c. The following decay method described in detail decay corrects each reading, then averages these calculated activities, and then divides the average by the time corrected reading to determine a correction factor. If the correction factor is between certain values, the calibrator is linear.

Decay Method

1 Zero the Background by pressing the Zero Background (Bkgnd) button.

2 Assay the Tc-99m syringe or vial in the dose calibrator to obtain the activity. This first assay should be done in the morning at a convenient time, for example, 8 A.M.

3 Repeat steps 1 and 2 several times per day until the displayed activity is 10 microcuries or below the lowest activity assayed in accordance with applicable State/NRC regulation or the condition of your license. One should collect 2 to 4 readings per day. Additional readings are acceptable depending on the isotope used.

   If the display indicates less than 50 μCi, (1.85 MBq), wait 30 seconds before recording the reading. To get a faster reading on the Atomlab 100, 100 Plus, 200 and 300, press the Mo-99 button and then the Tc-99m button, or adjust the transition threshold on the AtomLab 400 or 500 controllers. Record the date, time (to the nearest minute), and activity for each reading.

NOTE: Some state regulations allow linearity tests to end at activities greater than 10 μCi. You may discontinue the linearity test at the activity which your state regulations or license permit.

NOTE: Use of a spreadsheet, such as Microsoft Excel, in steps 4 and 5 will simplify calculations.

4 Convert the time and date information you recorded to hours (t) elapsed since the first assay. Decay-correct each displayed activity measurement (M) using the equation,

$$M_0 = M \cdot (2)^{\frac{t}{T_{1/2}}}$$

where $T_{1/2} = 6.007$ h. Record the values. See linearity form, Figure 1. Calculate activity correction factors (cf) by dividing the average of all decay corrected measurements ($\overline{M_0}$) by each M_0, i.e.,

$$cf_M = \frac{Average\ of\ all\ M_0}{M_0(t)}$$

Accept if $0.95 < cf_M < 1.05$. Consider correcting the displayed activity measurement (M) of radio pharmaceuticals if a linearity error is greater than ± 5% and less than ± 10%, i.e., $0.90 < cf_M < 0.95$ or $1.05 < cf_M < 1.10$. Corrected $M = M * cf_M$ where subscript M is closest in value to M in most recent linearity form. For low activity values, if $cf_M < 0.95$ see the following note about Mo-99 contamination.

NOTE: If there is any Mo-99 contaminant in the Tc-99m sample, then long decay times (>48h) will compromise the decay linearity test. This will be apparent with decreasing cf_M values for the lowest displayed activity measurements (M). In order to test for this, prepare another linearity test sample with an activity of about 1 mCi. Repeat the linearity test. If the cf_M values are within an acceptable range and if the 1st linearity test by decay produced acceptable cf_M values at higher M values, then the dose calibrator passes. The two linearity tests should have overlapping activity values in the acceptable range.[1] *Hint: Recalculate first test ($\overline{M_0}$) without including failing values from low (M) Mo-99 contamination.*

5 If $cf_M < 0.90$ or > 1.10, contact Biodex technical support and provide full details, including all linearity decay data.

Attenuation Tube Method or Sleeve Test Method

If you decide to use a set of "sleeves" of various thicknesses or combination of sleeves to test for linearity, it will be necessary to first use the Decay Method to show the calibrator is linear. Then immediately repeat the test. Follow the directions furnished with your lead sleeves (i.e. Linearator instructions.)

If failure occurs at the low activities, check for Mo-99 contamination by repeating the test with 1 mCi. See NOTE under "Decay Method," step 4.

NOTE: You can perform the Sleeve Test procedure first and immediately perform a traditional Linearity test. This allows the user to perform both tests with one dose.

NOTE: Other isotopes can be used to perform linearity, such as F-18. The sleeves can only be used with Tc-99.

1. See "Quality Control Testing of Dose Calibrators," R.Y.L. Chu and W. E. Simon, Journal of Nuclear Medicine Technology, 24, #2, June 1996, pp 124-128.

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AtomLab Dose Calibrator Linearity Test, Model: _____ Serial Number:_____

Date	Time	Activity Measured, *M*	Hours elapsed, *t*	$M_{0,t}$	$cf_M = Avg / M_{0,t}$
			Avg:		

Accept if $0.95 < Avg / M_{0,t} < 1.05$

Figure 1. Sample dose calibrator linearity test data collection form

Rev. F, 2/15/10

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Geometry

Geometry Independence means that the indicated activity does not change with volume or configuration of the source material. This test should be done using a syringe that is normally used for injections. The following test assumes injections are done with 3 ml plastic syringes and that radio pharmaceutical kits are made in 30 ml glass vials. If you do not use these, change the procedure so that your syringes and vials are tested throughout the range of volumes commonly used.

If a significant volume correction results from these procedures, the tests should be repeated to verify. AtomLab dose calibrators have been tested for volume dependence in beta measurements which are expected to be worst case and the results were 0.13 %/ml. [2]

Syringe Test (example)

1 In a small vial, mix 2.0 ml of a solution of Tc-99m with an activity concentration between 1 and 10 mCi/ml.
2 Set out a second small vial containing non-radioactive saline solution.
3 Draw 0.5 ml of the Tc-99m solution into the syringe and assay it.
4 Record the volume and activity of the first assayed sample (Figure 2).
5 Remove the syringe from the calibrator, draw an additional 0.5 ml of non-radioactive saline into the same syringe (total volume 1.0 ml), and assay again. Record the volume and measured activity on the form.
6 Repeat step 5 twice more until you have assayed 1.5 ml and 2.0 ml volumes and recorded them.
7 Assay the vial used to draw saline into the syringe. If the measured activity is greater than 1% of the 0.5 ml syringe assay, Tc99m was lost during filling. Repeat the procedure.
8 Divide the average activity by the activity indicated for each volume. The quotient is a volume correction factor.
9 If any correction factors are greater than 1.05 or less than 0.95, it will be necessary to make a correction table that will allow you to convert from "indicated activity" to "true activity." If this is necessary, be sure to label the table "syringe geometry dependence", and note the date of the test as well as the model number and serial number of the dose calibrator.

Vial Test (10 ml) (example)

1 To test the geometry dependence for a 10 ml glass vial, draw 1.0 ml of Tc-99m solution (between 1 and 10 mCi/ml) into a syringe and inject it into the vial. Assay the vial. Record the volume and activity indicated.
2 Remove the vial from the calibrator and, using a clean syringe, inject 2.0 or 3.0 ml of non-radioactive saline, and assay again. Record the volume and activity indicated on the form (Figure 2). Repeat the process until you have assayed a 8.0 ml volume. The entire process must be completed within ten (10) minutes, or, if not, decay-correct the activity.
3 Divide the average activity by the activity indicated for each volume. The quotient is a volume correction factor.
4 If any correction factors are greater than 1.05 or less than 0.95, it will be necessary to make a correction table that will allow you to convert from "indicated activity" to "true activity." If this is necessary, be sure to label the table "vial geometry dependence", and note the date of the test and the model number and serial number of the calibrator.

NOTE: Perform the vial test with the vial size you commonly use.

NOTE: Other isotopes can be used for performing Geometry testing.

2. See "Accurate Dose Calibrator Activity Measurement of Y-90 Ibritumomab Tiuxetan," J. A. Siegel et al, J Nucl Med, 2004, 45:450-454.

AtomLab Dose Calibrator Geometry Test, Model:_____ Serial Number:_____

Syringe:	Type_____	Volume_____	Decay correct if test not completed in 10 min.	
Date	*Time*	*Volume*	$(Activity)_v$	*Volume cf = Avg/$(Activity)_v$*
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
		Avg:	_____	

Vial:	Type_____	Volume_____	Decay correct if test not completed in 10 min.	
Date	*Time*	*Volume*	$(Activity)_v$	*Volume cf = Avg/$(Activity)_v$*
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
		Avg:	_____	

Figure 2. Sample AtomLab dose calibrator geometry test form

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Accuracy

Accuracy means a determination of the dose calibrator's absolute error resulting from a measurement of a suitable NIST-traceable radionuclide activity. Traceable sources are available from NIST and from many radioisotope suppliers. At least two sources with different principal photon energies (such as Co-57, Co-60 Cs-137 or Ba-133) should be used. One should have a principal photon energy between 100 keV and 500 keV.

1. Press the Zero Background (Bkgnd) button which zeroes the dose calibrator.
2. Assay a calibrated reference source of appropriate activity at the appropriate setting (i.e., use the Co-57 setting to assay Co-57). Record the displayed activity measurement, *M*, the date, and the reference source identification (nuclide, activity, date of calibration, serial number, model number, and manufacturer.)
3. Take 3 readings for the reference source. Remove and reinsert the reference source between readings.
4. Repeat the procedure for the other calibrated reference source.
5. For both sources, decay-correct the reference source activity value and record as "true activity."
6. Calculate the average for the 3 measurements and compare the average to the calculated activity.
7. Calculate activity measurement % error from:

$$\%\ Error = \left(\frac{M - True}{True}\right) 100$$

8. Evaluate the calculated % errors according to the approximate location of the dots in Figure 3 and take the recommended action corresponding to your error condition.

NOTE: It is recommended that the Cs-137 and Ba-133 sources be replaced when the activity is below 100 µCi. It is recommended to replace a Co-57 source when the activity is less than 1 mCi.

Error Condition	Percent Error*						Recommended Action
	-10	-5	0	+5	+10		
Between 0 and -5%			• •				None.
Between 0 and +5%				• •			
Less than ±5%			•	•			
Large difference, skewed low		•		•			Probable source calibration activity error. Examine sources with error > 5%, < 10%.
Large difference, skewed high			•		•		
Both skewed low		•	•				Probable dose calibrator error. If average error ≤ 5%, continue use. If average error ≥ 5% contact manufacturer. Continue use under advisement.
Both skewed high				•	•		
Both high within tolerance					• •		Contact manufacturer. Continue to use under advisement.
Both low within tolerance		• •					
Both high, straddling 10%					•	•	Contact manufacturer to return for repair.
Both high, outside tolerance						• •	
Both low, straddling 10%	•	•					
Both low, outside tolerance	• •						

* A dot represents a source accuracy error. Dot location represents any value between the error bars. For example, in the 3rd row, the left dot indicates a source error of any value between -5% and 0% and the right dot any value between 0% and +5%.

Figure 3. Recommended action for Accuracy test error conditions

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Records and Maintenance

Records

Article 10 CFR 35.2060 requires that a NRC licensee maintain instrument qualification records for 3 years. The records must include the model and serial number of the instrument, the date of the qualification, the results of the qualification, and the name of the individual who performed the qualification.

Dipper and Well Liner

Inspect the instrument on a quarterly basis to ascertain that the well liner is in place and is not damaged. Check for contamination of the liner and dipper as follows:

1 Remove the plastic dipper and liner from the well chamber.
2 Press the Zero Background (Bkgnd) button to zero the calibrator.
3 Put the liner back in. If the display reading increases, the liner may be contaminated.
4 If the liner is OK, put the dipper back in and check for contamination.
5 If any part is contaminated, you must decontaminate or replace the item and then recheck for contamination.

Dial Value Checks—Monthly

Each isotope button is programmed with a specific dial value (DV). The user can adjust the DV for a particular need. Each isotope button should be checked periodically to verify it is set to the correct dial value for that isotope. The method of displaying the dial values varies by model; consult the operation manual for your dose calibrator to see how to display the dial values.

NOTE: The Dial Value check is to verify that no one has accidentally changed the Dial Value from the factory settings or the appropriately determined facility settings.

Repair or Replacement

Consider repair or replacement, if the dose calibrator falls outside the suggested tolerances.

If repair or replacement is required, contact Biodex Medical Systems for instructions.

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DATE ON REPORT OF CALIBRATION FOR ATOMLAB DOSE CALIBRATOR

SIGNIFICANCE AND EXPIRATION

The Report of Calibration that accompanies the Atomlab Dose Calibrator is intended to represent evidence that the product was calibrated by the manufacturer before it was shipped. This report does not serve as an exemption to the accuracy test that is required at installation of the product in the facility where it will be used.

The date on the Report of Calibration does not expire since the report is not useful, in the typical sense, as a record of calibration in a periodic maintenance schedule.

For example, when a survey meter is purchased, it normally comes with a calibration certificate, dated within the past 6 or 12 months. This meter is then placed on a re-calibration schedule, as determined by local regulations. The re-calibration date may be scheduled from the original calibration date, or simply placed on the institution's normal schedule interval for such meters.Re-calibration requires the meter be shipped to a laboratory that is licensed to perform such a task. There is no need to check the accuracy of the survey meter upon installation at the facility; the facility generally has no means to check the accuracy of a survey meter.

The situation and requirement is different for Dose Calibrators. Although modern manufacturing capabilities have improved the robust nature of dose calibrator systems, these products tend to be more fragile than survey meters. Therefore, the NRC determined at an early date that the dose calibrator accuracy must be tested on site, prior to its introduction into clinical use. This was prudent since, a) the dose calibrator was being used to measure radionuclides prior to administration to a patient and, b) the availability of sealed long lived isotopes made this accuracy test very reasonable at a clinical facility.

The NRC now requires the facility using a dose calibrator to implement the Manufacturer's Instructions for Quality Assurance Testing of Dose Calibrators. Such Instructions accompany all Atomlab Dose Calibrators, and requires the Accuracy test" at installation and at least annually thereafter. After repair of the dose calibrator, repeat the above tests as a new installation."

Therefore, the date on the Report of Calibration cannot be used as a substitute for the installation accuracy test. The only significance of the date is when the dose calibrator was calibrated at the manufacturer. It never receives another calibration unless it is returned to the manufacturer. The accuracy test at the facility is not a calibration; it is simply an accuracy test stating that the dose calibrator measures a specific radionuclide within a stated error. The date on the Report of Calibration does not expire until the dose calibrator is returned to the manufacturer.

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APPENDIX K:
ATOMLAB 400 REPLACEMENT PARTS

ATOMLAB 400 REPLACEMENT PARTS

C11782	Adapter, AC to DC, Ext. 15VDC
086-330-E601	DC Function Pad
086-335-E745	LCD Display Board Assy
086-335-E800	Display Board, Atomlab 400
086-241	Well Insert
086-242	Well Vial/Syringe Dipper
C13116	Power Supply
086-330-E705	Chamber Cable
C8187	Bumpons, Self Adhesive, Grey

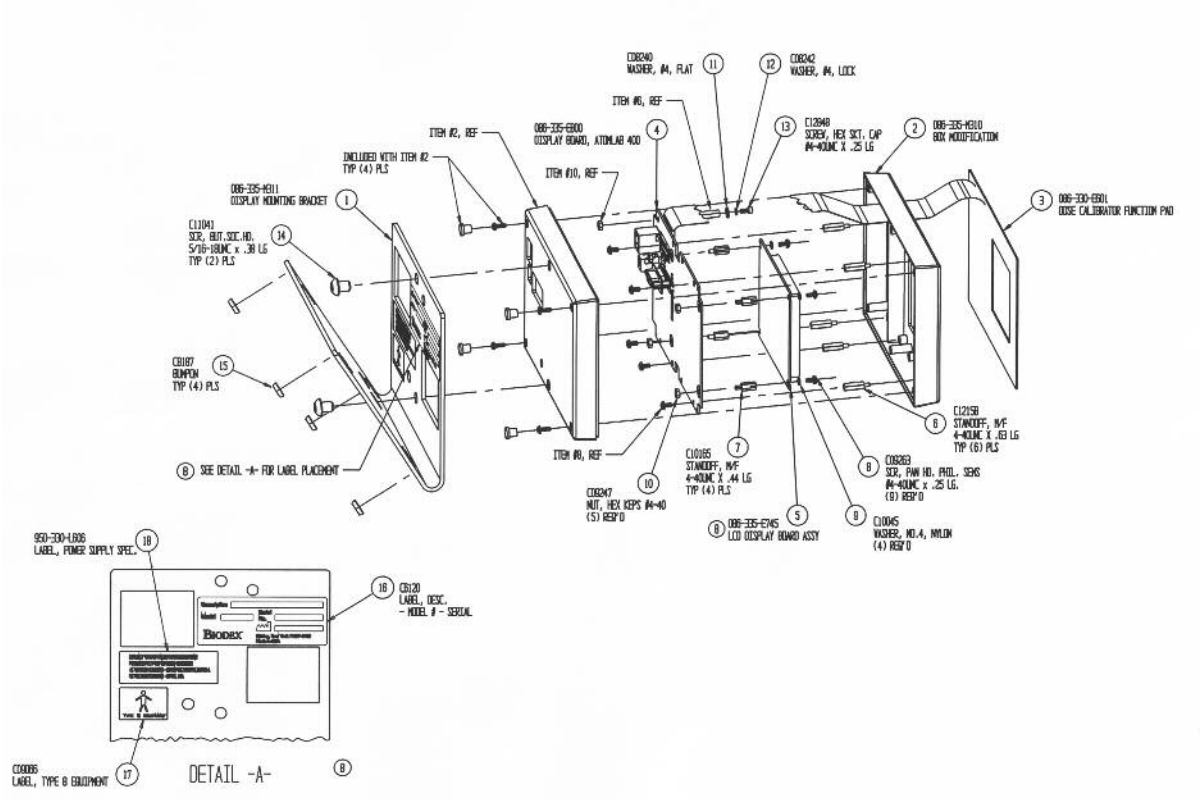

Figure K.1. Atomlab 400 replacement parts.

APPENDIX L:
SCHEMATICS

Certified Quality Management System

BIODEX

Biodex Medical Systems, Inc.
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